OPERATIONAL SUITABILITY

EVALUATION HANDBOOK

Version 2.0
5 July 2022

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RECORD OF REVISIONS

Change Number	Summary of Changes	Updated
1	Incorporates updated logistic supportability guidance & clarifies mean logistic delay time calculations, updates measure & data requirement appendices, clarifies duty cycle examples. Incorporates updated command name and logo throughout.	15 June 2022

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Forward

To succeed in our mission to "ensure Naval Forces can fight and win by evaluating warfare capabilities in realistic combat environments with Fleet warfighters," Operational Test and Evaluation Force (OPTEVFOR) must thoroughly evaluate Operational Suitability. Systems must be reliable, maintainable, logistically supportable, and available for use when required. Systems that are 100 percent effective at hitting a target if fired, yet are rarely available to be fired when needed, do not support mission accomplishment. Therefore, determining a system's suitability is just as important as determining its effectiveness and its cyber survivability. To understand whether a system is capable of supporting mission tasking in an operational environment, we must determine the likelihood that it will be operable and ready when called upon. Suitability is evaluated via multiple Critical Operational Issues (COI) with Availability at the center, supported by thoroughly understanding the contributions of Reliability, Maintainability, and Logistic Supportability.

This handbook was prepared to help the OPTEVFOR team: military, civilian, and support contractors, conduct disciplined and thorough Operational Suitability evaluations. It describes the evaluation process, starting from a broad perspective, and working down into the details of individual measures and formulae. Each test team is expected to apply critical thought to the selection of suitability measures and test methods. No two programs are identical, and no one method of evaluation will apply to all programs. This is especially true when evaluating accelerated acquisition systems, where we must use all tools and data sources available to provide a well-reasoned assessment of risk to the Fleet. Using this handbook while working with the test competencies, and as approved in the Integrated Evaluation Framework and Test Plan development processes, the test team will optimize a Suitability test strategy appropriate for their System Under Test (SUT). Most importantly, that test strategy will lead to impartial and defendable test results that will be reported as the Operational Truth to the Fleet.

This handbook is OPTEVFOR policy for evaluating Operational Suitability. It shall also be the basis for training courses conducted by OPTEVFOR. Just as you are expected to develop an evaluation strategy, based on the principles in this handbook, you are also expected to tailor it to the needs of your particular program, working in collaboration with program offices, Director, Operational Test and Evaluation (DOT&E) (when appropriate), and the Fleet. When critical thinking is applied to the methods contained herein, the Operational Test Team will be well prepared to conduct our vital mission on behalf of the Fleet.

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Introduction

A system that is not Suitable**,** when employed in an operational environment, provides no value to the warfighter, regardless of how effective it is at supporting mission critical tasks. In addition, Suitability issues tend to be the largest drivers of system life cycle costs. For these reasons, it is important to ensure Suitability evaluations, during Operational Testing (OT), provide meaningful and actionable results for both the Program Manager and the Fleet. This can be challenging, especially since tests are not often sized for Suitability, instead relying on limited test windows to provide the data needed for the evaluation. This creates the need to have a solid game plan, built on a sound evaluation strategy, in order to maximize our learning in testing. This is especially true when evaluating systems developed using accelerated acquisition. In those situations, the test team will be faced with aggressive timelines, short test durations, and limited resources. It is incumbent on test teams to explore innovative test strategies, identify all potential sources of data, and effectively evaluate system performance to articulate a well-reasoned assessment of risk to the Fleet.

This handbook describes the policy, principles, and philosophical approach that shall be used in evaluating Operational Suitability. It presents the tools and techniques to help you develop a suitability evaluation strategy based on an interconnectedness between Reliability, Maintainability, Logistic Supportability, and Availability (RML&A). The thread that provides this connection is the Operational Mission Failure (OMF). OMFs help not only in understanding Reliability, but also provide the opportunities to understand Maintainability and Logistic Supportability as they are corrected. The information contained in this handbook will help you establish this connection and develop a strategy that will aid in understanding the System under Test's (SUT) Availability and ultimately its Suitability.

The Availability COI is central to the SUT suitability assessment/evaluation, and is supported by the Reliability, Maintainability, and Logistic Supportability COIs. To be operationally suitable, the SUT must be available; and to be available, the SUT must be reliable, maintainable, and logistically supportable. This handbook provides guidance to Operational Test Directors (OTD) and Test Teams and applies to Integrated Evaluation Framework (IEF) development, test planning, execution, analysis, and reporting.

The guidance contained in this document serves as a foundation for the Reliability, Maintainability, Logistic Supportability, and Availability (RMLA-100) training course, available for OPTEVFOR personnel. This document provides the "what" – the policy is presented within an analytical context. However, this is not intended to be a comprehensive guide on "how" to implement every aspect of the analytical methodology. RMLA-100 provides additional insight to the "how."

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CHAPTER 1 - Operational Suitability

Operational Suitability is the companion to Operational Effectiveness and Cyber Survivability in OT&E. These three evaluation areas, combined, provide a complete picture of how well a system supports the warfighter in accomplishing tasks. Suitability specifically addresses the system's capability to continue to support the warfighter when needed, and the Fleet's ability to supply and maintain the system.

1.1 SUITABILITY CRITICAL OPERATIONAL ISSUES (COI)

Operational Suitability, as defined in Office of the Chief of Naval Operations Instruction (OPNAVINST) 3000.12A[1] and the Defense Acquisition University (DAU) Glossary[2] is "the degree to which a system can be satisfactorily placed in field use with consideration to reliability, availability, compatibility, transportability, interoperability, wartime usage rates, maintainability, safety, human factors, habitability, manpower supportability, logistic supportability, documentation, environmental effects, and training requirements." This formal definition includes all 15 areas depicted below in figure 1-1. However, that does not mean each area must be evaluated using a separate COI.

Figure 1-1. Operational Suitability Areas

Reliability	Availability	Compatibility	Transportability	Interoperability
Wartime Usage Rates	Maintainability	Safety	Human Factors	Habitability
Manpower Supportability	Logistic Supportability	Documentation	Environmental Effects	Training Requirements

In the past, suitability COIs included many of these areas, more than just Reliability, Maintainability, Logistic Supportability, and Availability. However, not everything related to the concepts in figure 1-1 automatically belong in Suitability. Often, test observations can overlap between Effectiveness and Suitability. A vital part of planning for, executing, and reporting on the Suitability aspect of testing is making the separation between Effectiveness and Suitability concerns. When a system is operating as designed, with all the necessary resources to function correctly, any issues encountered are almost certainly Effectiveness. Any time the system does not operate as designed, those issues then belong to Suitability. Consider the following examples:

- Documentation: If the tactical guidance has not been updated/provided for the SUT, then that is a Suitability (Logistic Supportability) problem. Yet, if the documentation is written poorly, and does not support system operation, the associated Effectiveness task suffers as a result and the poor documentation issue is reported as an Effectiveness problem.

[1] OPNAVINST 3000.12A, 2 September 2003
[2] DAU Glossary, https://www.dau.mil/glossary/Pages/Default.aspx

- Human Factors: If the system is cumbersome to use and tasks are accomplished more slowly or less accurately, that is Effectiveness. However, if the system is delicate and easily broken, this is Suitability.
- Compatibility: If a system requires more cooling than is supplied, and the system fails often, or must operate at a reduced capacity as a result, that belongs in Suitability (Reliability). However, if full system function is available, yet the variability of system operating temperatures causes variability in task accomplishment, that belongs in Effectiveness.
- Transportability: If transport is part of the mission Concept of Operations, (CONOPS) that is Effectiveness. However, if transport is a function of supply, that is Suitability.

These other areas are best evaluated as they contribute to either the four standard Suitability COIs or the appropriate Effectiveness mission areas.

The OPTEVFOR standard suitability COIs are:

- S-1, Reliability
  - Will [SUT] reliability support mission accomplishment?
- S-2, Maintainability
  - Will the [SUT] be maintainable by Fleet personnel?
- S-3, Logistic Supportability
  - Will the [SUT] be logistically supportable?
- S-4, Availability
  - Will [SUT] availability support mission accomplishment?

In the case of most programs, these four standard suitability COIs ***shall be evaluated***. However, Maintainability and/or Logistic Supportability may not apply to some systems. For example, a chem-bio wipe for decontamination cannot be repaired, and needs no Maintainability COI. An upgraded SUT, which has the same logistics support as the previous increment, may not need a Logistic Supportability COI.

Evaluation of these COIs starts with specific critical measures, regardless of whether they have specified thresholds associated with them. If the measure is specified in the requirements document, the test results will be compared to the specified threshold. Measures derived from SUT documentation, other than the requirements document, or that have no SUT source documentation, may not have associated criterion. These quantitative test results will be assessed qualitatively as a part of COI resolution. Ultimately, all measures will be evaluated against their impact to mission area(s), and will inform the resolution of the suitability COIs.

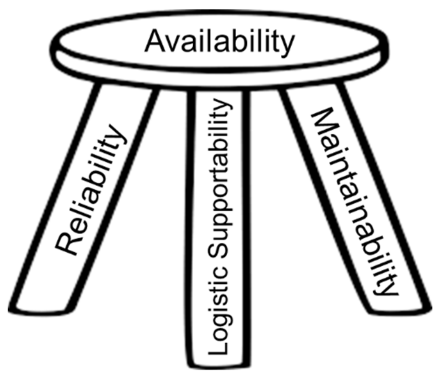
Although traditional Suitability areas (depicted in figure 1-1) are addressed typically via one of the four standard Suitability COIs or an Effectiveness mission area, this does not preclude using them when necessary to evaluate a specific capability. For example, if a system has a significant training component (e.g., simulators, part task trainers, standing up a schoolhouse, etc.), consideration should be given to using a Training COI. Evaluating training, via its own COI, enables a more detailed and comprehensive evaluation.

1.2 THE RML&A RELATIONSHIP

It is important to understand the four standard COIs (i.e., Reliability, Maintainability, Logistic Supportability, and Availability) are inextricably linked (for repairable systems[3]). These four COIs not only link to, but also determine Operational Suitability. To be operationally suitable, the SUT must be available; and to be available, the SUT must be reliable, maintainable, and logistically supportable. These linkages are present, both conceptually and mathematically. In the majority of cases, if the test is designed and planned correctly, the calculation of A_O (operational availability) will provide the preponderance of evidence in determining whether the SUT is operationally suitable.

Imagine a stool with three legs, as in figure 1-2, with Reliability, Maintainability, and Logistic Supportability as the legs, and Availability as the seat. All three legs need to be functional for the stool to stand. If any of the legs break, the stool will fall; it cannot stand. This same concept holds for Availability and the other three COIs. If a system is not reliable, not maintainable, and/or not logistically supportable, it cannot be available[4]. The whole point of a stool is the seat at the top. Availability is the key to suitability

Figure 1-2. The Three-Legged Stool Relationship



Looking at it from the perspective of each of the three COIs, depicted as the legs of the stool, if a system fails frequently (even if it can be repaired quickly), it can have a negative impact on Availability. If (when it does fail) a system is difficult to repair, downtime will accumulate, negatively affecting Availability. Additionally, if (while attempting to repair a system) downtime is extended, while awaiting logistical support, Availability is also negatively affected. Through this relationship, problems with one or more of the legs of the stool should be reflected in Availability. This should be noticeable qualitatively, as well as quantitatively via well-designed measures.

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[3] For non-repairable systems, Availability is informed primarily via an understanding of Reliability and Logistic Supportability. This applies mainly to Impulse systems (discussed later in this chapter).

[4] This analogy cannot be used in the same way for non-repairable or Impulse systems, such as missiles. For these, (in general) Availability is measured prior to launch, and Reliability is measured after launch. Although Logistic Supportability directly supports Availability, Reliability is not coupled in the same way.

The converse is also true. If all the COIs, depicted as the stool's legs, are evaluated as Satisfactory (SAT), in most cases Availability should also be SAT. If, in this case, Availability instead is evaluated as Unsatisfactory (UNSAT), then the data were neither captured nor scored properly; or the measures, used in testing, did not align throughout the stool. This idea of alignment will be explained in the next section.

One could argue so long as a system is reliable "enough" (imagine a case of very high reliability), Maintainability and Logistic Supportability are less important. Although true, this does not invalidate the relationship; in fact, the contrary is true. It demonstrates (using an understanding of the stool) how systems engineering and design can be used to boost one or two of the legs to mitigate limitations of the other(s).

One might ask, "if the impact of Reliability, Maintainability, and Logistic Supportability are reflected (cumulatively) in Availability, and if Availability (in most cases) determines Operational Suitability, then why not just measure A_O, and minimize the resources that would otherwise be wasted evaluating the other three COIs?" The answer to this lies in the "why?" Whereas A_O (if used properly) should say if Availability is insufficient to support mission accomplishment, it does not say why. Determining what specifically is "influencing availability" is essential to helping the program office determine how to fix the problem, and help the Fleet determine how to mitigate the shortfall. For example, if Availability is evaluated UNSAT, due to problems with Logistic Supportability (specifically, in obtaining parts to repair critical failures), then the problem might be mitigated by prepositioning additional critical spare parts on the ship or at the squadron. Alternatively, if the problems were due to Reliability, the program office might direct efforts to address specific failure modes discovered during testing.

Closing the stool metaphor, recognize the seat of the stool contains material separate from the legs. Similarly, availability evaluation may require consideration of data separate from Reliability, Maintainability, and Logistic Supportability (RM&L). This idea will be clarified through discussing defining times in section 1.5. Even if all three legs of the stool are strong, the seat can still break.

1.3 THE LIFE CYCLE OF A FAILURE

As explained in the previous section, one generally can understand the Suitability of a system by measuring its Availability. However, that may only tell part of the story. Overall testing time might be very short, providing few opportunities to observe failures and their subsequent restoration, or the SUT may be highly reliable and not provide sufficient opportunities to evaluate real maintenance and/or logistic support in action. In order to fully understand the Suitability of the SUT, a combination of sufficient System Operating Time (SOT)[5], and an adequate number (and types) of failures is ideal, thus making an assessment of A_O meaningful, while providing the opportunity to more fully evaluate Reliability, Maintainability, and Logistic Supportability. For repairable systems, the information provided through observing the life cycle of failures, specifically OMFs[6], is invaluable to understanding Reliability, Maintainability, Logistic Supportability, Availability, and the connections between these COIs. Figure 1-3 illustrates how a single failure helps do that.

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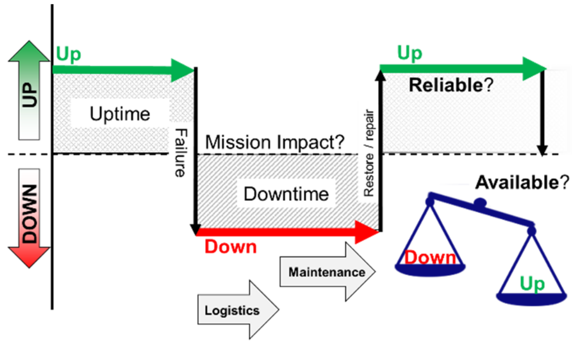
[5] SOT adequacy is discussed in Chapter 2, Reliability, section 2.6.
[6] Failure types are defined in Chapter 2, Reliability, section 2.2.

Figure 1-3. Life Cycle of a Failure



Availability is measured as the ratio of uptime to total time[7] (for a continuously operating system). An operating SUT accrues uptime. When a failure occurs, one is able to observe the mission impact of that failure. The decision to score it as an OMF comes later. If the failure occurred within a mission-critical subsystem (i.e., the failure was an OMF), the SUT is no longer mission capable and downtime accrues. One is then able to assess Maintainability as the failure is repaired. If the repair requires logistical support, then one can also assess Logistic Supportability. Once the failed subsystem is repaired and restored to a Mission-Capable Condition, one can then capture the downtime for this failure, which enables an understanding of Availability. As long as the observed conditions are operationally representative, this life cycle provides the opportunities to assess/evaluate Availability and the contributions of Reliability, Maintainability, and Logistic Supportability to it. The OMF is key to this evaluation process. It is the common thread tying all these parts together. This point will be reinforced in the next four chapters, as OMF-centric measures are discussed and tied together. Before developing those measures, one must first understand the SUT.

1.4 UNDERSTANDING THE SYSTEM UNDER TEST (SUT)

Planning and executing a test, then analyzing results and evaluating the system, first require understanding what comprises it and how the system is intended to be used from both a mission area perspective and general CONOPS. The following sections provide a framework of elements, useful in understanding the SUT from a suitability perspective. Most SUTs are complex systems, which are composed of multiple mission-critical subsystems that may operate in series, in parallel, or in some combination of both. For multi-mission SUTs, such as aircraft, ship, or submarine platforms, the configuration and/or list of mission-critical subsystems may vary by mission area. Because each SUT is unique, understanding the SUT configuration is critical to measure selection, data scoring, and subsequent analysis. Explicit consideration should be given to identifying mission-critical subsystems, redundancies in mission capability across subsystems, the duty cycle of the SUT, and the sustainment concept.

1.4.1 Mission-Critical Subsystems

Developing the Mission-Critical Subsystem Matrix (MCSM), depicted in table 1-1, is the most critical step in understanding and documenting the SUT configuration for Suitability evaluations. The matrix cross-references SUT subsystems to the mission areas, for which a capability or function provided by the subsystem is required. The mission areas are listed horizontally at the top of the matrix. Mission-critical

[7] Time, as used during operational testing, is discussed in section 1.5.

subsystems and redundancy information may be identified explicitly in requirements documents or other program documentation, such as Mission Essential Subsystem Matrices (MESM) for mature aviation systems. Depending on the degree of technical detail provided by program documentation, additional subsystems may need to be considered for completeness. The mission-critical subsystems are listed vertically in the far left column of the matrix. In addition to identifying the mission areas that require the subsystem, its level of redundancy is included. Specify the number of subsystems required to continue operation of the SUT and the total number of subsystems. For example, a ship may have three chill water air conditioning systems, yet only two operational systems are required to conduct each mission area. Redundancy for a particular subsystem can vary by mission area, and this should be identified in the table as well. Finally, for each mission-critical subsystem, its duty cycle is identified (see section 1.4.3).

Table **1-1. Sample Mission-Critical Subsystem Matrix**

Component	**Redundancy**	**Duty Cycle**	**E-1 AW**	**E-2 SUW**	**E-3 MIW**	**E-4 MOB**	**CS**
Propulsion and Maneuvering							
Main Diesel Engines	1 of 2	Intermittent	X	X	X	X	X
Propulsion Gas Turbines	1 of 2	Intermittent	X	X	X	X	X
Communications							
Link-16	1 of 2	Continuous	X	X	X		
Tactical Common Data Link	2 of 2	Continuous		X	X		
SHF		Continuous			X	X	X
Engagement Weapons							
57 mm gun		On-Demand		X			
RAM Launcher		On-Demand	X				
Support Craft							
MH-60S		Intermittent		X	X		
7-meter RHIB		Intermittent		X		X	
Auxiliary Systems							
Chill Water (A.C.)	2 of 3	Continuous	X	X	X	X	X
JP-5 Transfer	1 of 2	Continuous				X	X
Degaussing		Continuous			X		
Damage Control							
Fire Pumps / Firemain	1 of 3	Intermittent		X	X	X	X
AFFF Stations	2 of 3	Intermittent		X	X	X	X
Watermist	2 of 2	Intermittent				X	X

Redundancy is represented via k of n notation, where k = Number of subsystems required to meet mission requirements, and n = Number of subsystems provided in the redundant configuration.

AFFF – Aqueous Film forming Foam
AW – Air Warfare
CDD – Capability Development Document
CS – Cyber Survivability
JP-5 – Jet Propellant 5
MIW – Mine Warfare
MOB - Mobility
PM RBD – Program Manager Reliability Block Diagram
RAM – Rolling Airframe Missile
RHIB – Rigid Hull Inflatable Boat
SHF – Super High Frequency
SUW – Surface Warfare

The MCSM plays an important role in data scoring and analysis for Reliability as well as Availability. For complex multi-mission SUTs such as aircraft, ships, or submarines, understanding Suitability from a mission area perspective is more operationally meaningful than the measures associated with specified system-level requirements. This allows for better characterization of the mission impact of Suitability issues. This construct should not be misinterpreted as a means to incorporate Suitability performance in an Effectiveness COI resolution.

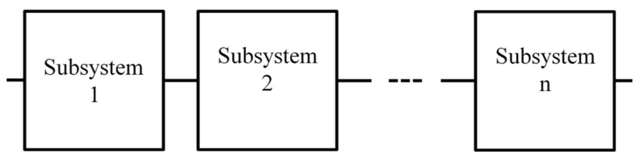
The mission areas, which capture the operational capabilities affected by the SUT, are identified at Touchpoint 1 of the Mission Based Test Design (MBTD) process. The mission areas inform the selection of Effectiveness COIs, and should provide the context for Suitability evaluation. This is when the MCSM should be developed.

1.4.2 Redundancy

Redundancy is defined as the duplication of systems, subsystems, components, or functions of a system, with the intent to increase Reliability and Availability. Understanding subsystem redundancy is important in identifying which combination of failures can result in an OMF. Systems can be configured in one of three ways:

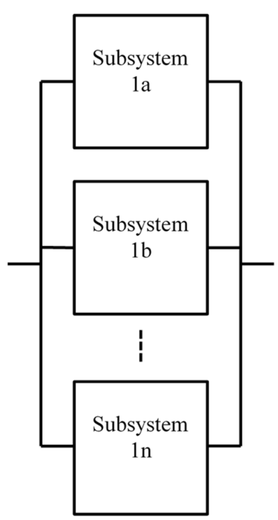
Series configuration: There is no Redundancy provided in this case. All subsystems or components must function for the system to operate. Figure 1-4 gives a conceptual view of a series configuration of "n" subsystems.

Figure 1-4. Block Diagram of Subsystems in a Series Configuration



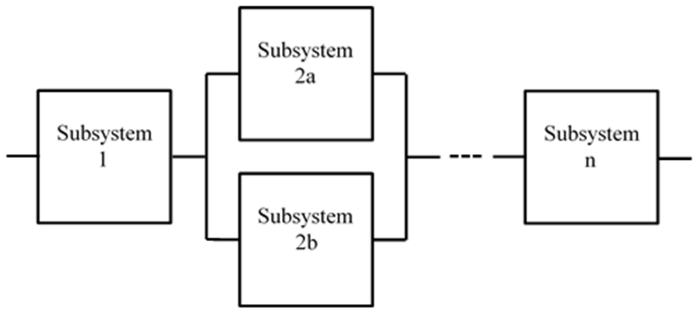
Parallel configuration: Redundancy is provided in this case. Only one subsystem or component must function for the system to operate. Figure 1-5 provides a conceptual view of a parallel configuration of "n" subsystems.

Figure 1-5. Block Diagram of Subsystems in a Parallel Configuration



Combined (serial and parallel) configuration: In this case, Redundancy is only provided for certain components. Many systems contain a combination of serial and parallel subsystems. Figure 1-6 provides a conceptual view of a combined serial and parallel configuration of "n" subsystems.

Figure 1-6. Block Diagram of Subsystems in a Combined Configuration



1.4.3 Duty Cycle

Duty cycle is defined as the frequency of system operation, and informs the selection of suitability measures for a given SUT. It is important to understand the duty cycle of each mission-critical subsystem within the SUT. This understanding is needed when measuring the Reliability of specific subsystems or when computing reliability of the SUT as a combination of its subcomponents (e.g., using a Reliability Block Diagram (RBD) method). For purposes of Reliability and Availability measurement and analysis, SUTs/subsystems are divided into four classes, and defined in terms of the way the SUT/subsystem is used[8]:

- *Continuous-use systems*: These are systems (nearly) always in use. Examples are networks, automated information systems, aviation mission computers, and aircraft engines from launch to recovery.
- *Intermittent-use systems*: These are systems, with relatively long periods of off-time between uses, where the length of time the system is in an operable state matters. Examples are ship engines, aircraft carrier arresting gear, aircraft (platform level), radars, radios, and machine guns.
- *On-demand systems*: These are systems, with relatively long periods of off-time between uses, where the length of time the system is in an operable state does not matter. Examples are hand-held weapons and torpedo launchers.
- *Impulse (single-shot) systems*: These are expendables generally used once. They are not recovered, nor returned to an operable condition through repair. Examples are bombs, missiles, and torpedoes.

SUTs and their subsystems must be classified by these definitions to calculate Reliability and Availability measures consistently and in a meaningful way, as the SUT duty cycle is used to determine which formula to use to calculate these measures (see chapters 2 and 5). In general, this document is written with a continuous system in mind. As needed, differences for other duty cycles will be called out.

[8] OPNAVINST 3000.12A, Operational Availability of Equipment and Weapons Systems, 2 September 2003

1.4.4 The Sustainment Concept

Understanding the sustainment concept is essential for proper test design. These are the details specific to the SUT necessary to score Suitability. The test team must understand the following items with respect to the SUT and address these, at a minimum, in the IEF, section 1.3.2:

- Operational Tempo (OPTEMPO)
- Maintenance concept
- Logistic concept
- Failure definitions
- Suitability definitions
- Critical components

Life cycle sustainment translates system capability and performance requirements into tailored product support to achieve system Suitability goals. Sustainment considerations include:

- Supply
- Maintenance
- Transportation
- Sustaining Engineering
- Data Management
- Configuration Management
- Human Systems Integration
- Environment, safety, and occupational health
- Protection of critical program information and anti-tamper provisions

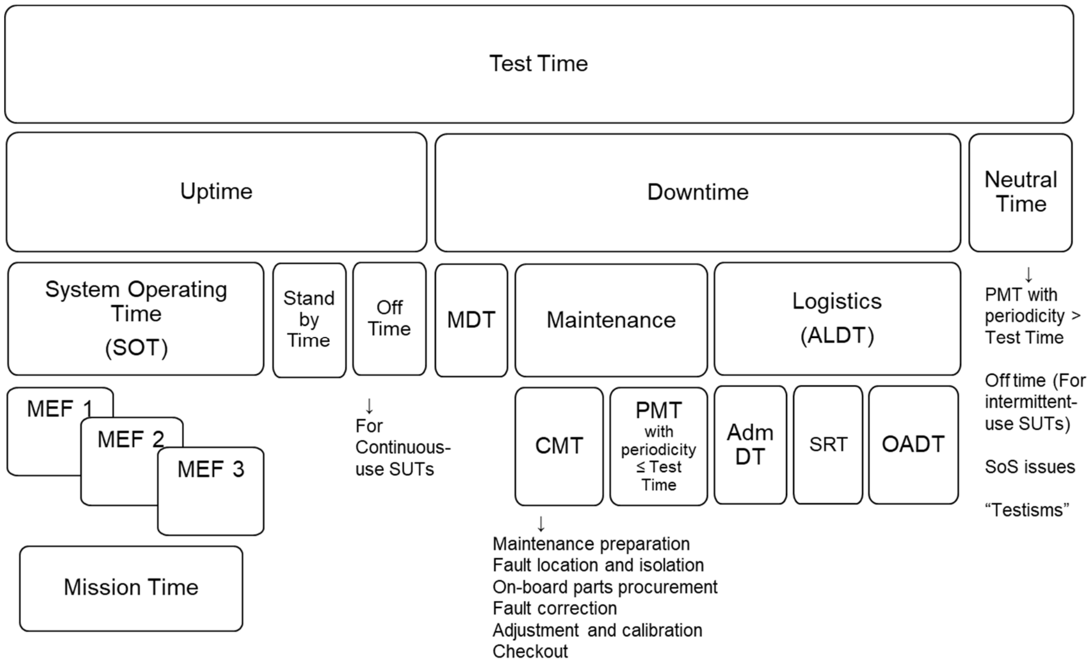
1.5 TIME

One last thing to explore, before looking at each of the COIs is *Time*.

1.5.1 Components of Suitability Time

In Operational Suitability testing, different categories of Time are used. It is important to understand, from a suitability perspective, how they all fit together. Figure 1-7 is a dendritic that breaks down the components of time used in OT into smaller and smaller pieces. All these times are used during most OTs. Any Time collected and analyzed during testing should be reflected somewhere on this chart.

Figure 1-7. RML&A Times



AdmDT – Administrative Delay Time	MEF – Mission Essential Function
ALDT – Administrative and Logistic Delay Time	PMT – Preventive Maintenance Time
CMT – Corrective Maintenance Time	OADT – Outside Assistance Delay Time
MDT – Maintenance Delay Time	SRT – Supply Response Time

The first of these is <u>Test Time</u>. Total Test Time is the calendar time from the beginning of test (i.e., start of test message), until after the last test event has been completed. Note, it does not continue until the end of test message is released. This is because the end of test message is not released until after all data are scored, which often can be up to 30 days after the last event. To properly evaluate Suitability, an OT would ideally begin with fully operational SUT articles, and would not end until the last OMF has been repaired[9]. This would give the most complete picture of RML&A. Unfortunately, this is not always the case. If forced to start testing with a test article that is not operational, downtime should immediately begin to accrue with all maintenance and logistics times being relevant. However, the (pre-test) failure that caused the SUT to be down in the first place does not count in Reliability calculations. Similarly, on the back end, if testing ends with failures, not yet corrected, the failures count toward Reliability calculations. However, the maintenance and logistics actions not completed will not be included in calculations.

The second level helps one understand Availability. It is composed of the following:

- <u>Uptime</u> – The system is operational and/or available for tasking.
- <u>Downtime</u> – The system is not operational (i.e., down for maintenance or logistics reasons), and cannot be called upon to support mission execution.

[9] In many cases, it is not feasible for a SUT to remain in testing until all failures are repaired.

- Neutral Time – Time cannot and should not be tracked for the system, because doing so would unfairly represent system Operational Availability.
    - Preventive Maintenance Time (PMT) – If the system is brought down to perform preventive maintenance, yet the periodicity requirement for that maintenance is greater than the total test time, this time should be excluded from Availability calculations.
    - Off Time – For intermittent-use systems, off time is not included. Only SOT and Standby Time (ST) should be included in uptime.
    - System of System (SoS) Issues – If the system is not capable of operating, due to lack of availability of the SoS, this time should be excluded from Availability calculations.
    - Testisms – If Downtime is caused by or extended due to factors, which are not operationally representative, this time should be excluded from Availability calculations.

The third level helps one understand Reliability, Maintainability, and Logistic Supportability. Each of the following times fall under uptime or downtime:

- System Operating Time (SOT) – The system is operating and being stressed under operational loads.
- Standby Time (ST) – The system is energized, yet not operating under an operational load.
- Off Time – For continuous-use systems, off time is a component of system uptime. Although it is not operating, it is assumed to be available.
- Maintenance Delay Time (MDT) – The system is down. However, maintenance and/or logistics actions are not being actively performed. This is due to operationally realistic circumstances that preclude the conduct of maintenance and logistic actions.
- Downtime associated with conducting maintenance.
- Downtime associated with off-board logistics.

The fourth level helps one understand what factors contribute to maintenance and logistics as well as how failures relate to mission essential functions.

- Mission Time – The system is being used to support the execution of a mission.
- Mission Essential Function (MEF) – The system is operating and being stressed under operational loads. This may occur before, during, or after the completion of a mission.
- Corrective Maintenance Time (CMT) – The system is down and active maintenance is being performed. This includes delays while obtaining onboard spare parts.
- Preventive Maintenance Time (PMT) – The system is brought down to perform preventive maintenance. This includes the amount of time the system is powered down and/or otherwise unavailable for use while performing Planned Maintenance System (PMS). Although the MPMT measure[10] considers all preventive maintenance actions (regardless of whether the SUT is made unavailable), PMT in this context includes only the time that is associated with a failure, therefore accruing downtime.
- Admin Delay Time (AdmDT) – The system is down, awaiting logistics resources other than spare parts. It includes time awaiting support equipment, technical data, training, facilities, etc.
- Supply Response Time (SRT) – The system is down and awaiting receipt of a spare component (from an off-board source).

[10] See Chapter Three – Maintainability.

- Outside Assistance Delay Time (OADT) – The system is down awaiting maintenance teams from other locations.

The next few chapters delve into each of these times, as they correspond to Reliability, Maintainability, Logistic Supportability, and Availability. After reading those chapters, one should have a clearer understanding of how RML&A times fit together, and how they help evaluate operational suitability.

1.6 MAKING RECOMMENDATIONS

In the final report, the test team has the opportunity to make specific recommendations to decision makers, Fleet users, and the program office. This can be particularly valuable, as they focus on particular issues requiring attention discussed in the report. When doing so, consider highlighting which failure modes should be the highest priority for the PM to address. These could be issues causing safety concerns for users. These could also be issues that most directly impact mission accomplishment, or drive system reliability. Although improving system reliability can be a clear target for recommendations, they can be used to address improvement in areas affecting any of the COIs. For example, consider addressing areas that could improve with increased spares, maintenance assets, training, or any issue, which negatively affects System Availability.

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2.1 DISCUSSION

Reliability is measured for three reasons: to evaluate system performance and inform decision makers; to provide data for program managers to aid in improving Reliability; and to inform Fleet users so they know what to expect when employing the system in an operational environment.

Reliability is the probability the SUT will perform without failure over a specified interval under specified conditions[11]. Reliability can be assessed by observing failures relative to time, number of events, stress cycles, miles, or any other reference to the frequency and/or duration of SUT operation. The following sections will define the types of failures used in operational testing. These sections will also define some common measures of Reliability with respect to those failures, and available options, when planned testing time is insufficient to fully evaluate SUT reliability.

2.2 HARDWARE FAILURES AND SOFTWARE FAULTS

All system Hardware (HW) failures and Software (SW) faults, impacting system performance or any operational mission, should be documented during OT. These failures/faults will occur primarily during execution of effectiveness vignettes that make up the bulk of the OT, yet can also occur between these vignettes, or during a vignette focused on suitability tasks. Then, all failures/faults observed should be scored to determine if they are OMFs, or non-critical failures. If possible, OMFs should be corrected during the test to provide the OTD an opportunity to collect Maintainability and Logistic Supportability data, for the reasons discussed in chapter 1 (section 1.3).

2.2.1 Basic Definitions

HW Failure – *A HW failure is a malfunction or inoperable state of a previously operable SUT or part of a SUT.* This excludes damage caused by (intentional or unintentional) improper operation of the system. Although it may be operationally relevant, a failure is not scoreable against Reliability if the system was used improperly, intentionally or not. Instead, it might be indicative of a usability issue, a training issue, or some other issue that may ultimately be a deficiency. For example, a system's operating checklist is incomplete (e.g., missing information on engine limitations). Thus, as a result of using that incomplete checklist, the operator induced a failure (e.g., exceeding an engine limitation). The resulting (engine) failure is not a scoreable failure [12] against Reliability (because the engine was not designed to exceed the limitation, and should not have been operated in the way that it was). Reliability also excludes operation outside the environment for which it was designed. These exclusions are important because the Reliability results must represent the likelihood of the system to experience a failure, while operating as it was designed to operate, under the conditions it was designed to operate. If a failure occurs outside the design envelope, and it is determined the mission requires the SUT to perform under those conditions (i.e., requirements did not adequately address the relevant conditions), there may be a deficiency or risk associated with the failure. However, Reliability will not be the affected COI (see section 2.3).

[11] DAU Glossary, https://www.dau.mil/glossary/Pages/Default.aspx
[12] A scoreable failure is one that is included in the calculation of Reliability measures.

Software Fault – *A SW fault is any interruption of system operation, not directly attributable to hardware.* It can be hard to distinguish between a SW fault and improper software design. For example, if a missile is tracking and guiding on a target; and its navigation software freezes, resulting in the missile discontinuing guidance and flying a ballistic profile into the ocean; it encountered a SW fault. Alternatively, if the missile guidance was coded (inadvertently) to assume a ballistic trajectory after 10 seconds time of flight, resulting in it flying into the water, it experienced a mission failure from an effectiveness standpoint due to improper SW design. In this case, there was no interruption in "normal" system operation. There was no SW fault; it operated as designed. It is important to distinguish between the two, as one relates to SW stability, and the other relates to SW design. Either one can still be a deficiency; the first one tied to Reliability, the second one tied to an effectiveness COI.

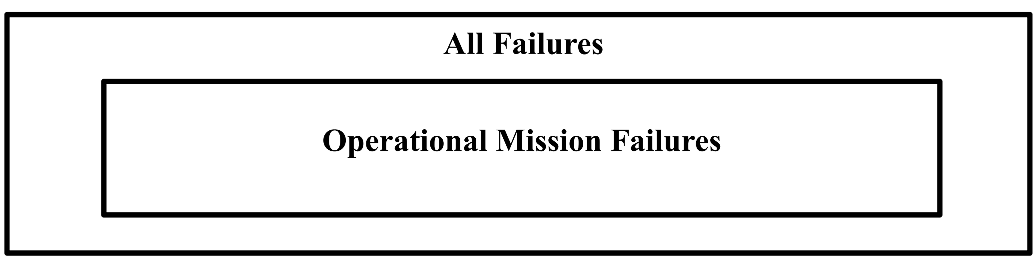
2.2.2 HW Failure/SW Fault Scoring

Scoring of failures is determined by considering the impact of failures on mission essential functions. It is important to understand the difference between each of them, and to understand how each are used to evaluate system reliability.

2.2.2.1 Operational Mission Failure (OMF)

An OMF is a HW failure or SW fault that prevents the SUT from performing one or more MEFs. MEFs are the minimum operational tasks, which the SUT must enable the operator to perform to accomplish an assigned mission. OMFs are a subset of all failures observed during OT (figure 2-1). The determination of whether a HW failure or SW fault is an OMF is made during the Operational Test Scoring Board (OTSB).

Figure 2-1. Relationship between All Failures and OMFs



2.2.2.2 Essential Function Failures (EFF)

It is important to recognize when capability requirement documents place restrictions on what can be scored as an OMF. This is known as "conditional scoring." Some examples of restrictions include limitations associated with when a failure or fault happens relative to a mission; how quickly it can be recovered; and whether it resulted in a mission abort. Examples include[13]:

- "OMFs are only scored during flight or when intent for flight exists"
- "Cannot complete specified mission, and downtime of 6 hours is allowed in one reliability mission"
- "Repeated failures or faults will only be counted the first time they are encountered"

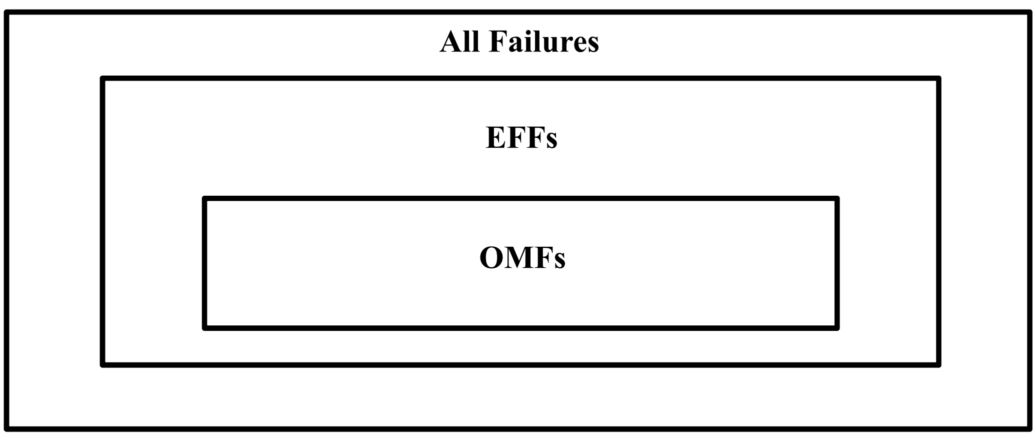
[13] Conditional scoring examples taken from actual program requirements documents.

It is worth noting subsystems that require certain redundancy criteria to be met before being scored as an OMF does not constitute conditional scoring. When requirements documents place conditional scoring limitations on the definition of an OMF, EFFs must be also tracked. In these cases, EFF-based measures will be used <u>in addition to</u> OMF-based measures.

An EFF is a HW failure or SW fault, which prevents the SUT from performing one or more MEFs, without applying the conditional requirements in the requirements documents. It is similar to an OMF, in that it would have been scored as an OMF, yet conditional scoring requirements precluded doing so.

Of note, conditionally-scored OMFs are a subset of the EFFs (figure 2-2). Measures associated with EFFs will be identified as critical because conditional scoring prevents a full and complete evaluation of SUT reliability. When EFFs are necessary, EFF-based measures will be used in all four primary COIs to provide the basis for the overall suitability evaluation (e.g., MTBEFF, MCMTEFF, MLDTEFF). **EFFs will only be used when conditional scoring exists for OMFs.** When using EFF-based measures, OMF-based measures will be reported as non-critical, but only those with specified thresholds.

Figure 2-2. Relationship between All Failures, EFFs, and OMFs (Conditionally-Scored)



2.2.2.3 Non-critical Failures

A non-critical failure is a HW failure or SW fault that may impact system performance, however it does not prevent the performance of any MEF.

During test, many failures/faults may be noted that are not scored as OMFs or EFFs at the OTSB. There may be redundancy associated with the failure, which allow system performance to continue for the mission. While these failures/faults are less critical, they can be incorporated into an associated OMF deficiency discussion, adding information or metrics that may describe total reliability of the component or sub-component in question. The repair of, or the recovery from, these non-OMF failures/faults may also better inform the Maintainability and Logistic Supportability evaluations.

2.3 OMF DEFICIENCY CONSIDERATION

All OMFs (or EFFs when used) observed during the OT evaluation phase should be considered for documenting in a Blue Sheet. Blue Sheets should be written for systemic failure modes adversely impacting SUT Availability or issues impacting user safety. For software, consider writing Blue Sheets for software stability or grouping OMFs by discriminating characteristics of the fault.

Consider writing a Blue Sheet if:

- The failed component operating hours did not exceed the design life,
- There is sufficient OT, Fleet, or program office data to suggest the failure is systemic,
- The failure mode is a safety issue.

The post-test data analysis summary shall contain an OMF supporting data table (sample depicted in table 2-1). This table will be presented at the System Evaluation Review Board (SERB), and will identify, for each OMF, the corresponding Blue Sheet. For OMFs with no Blue Sheet, a short explanation of the rationale shall be included.

Table 2-1. Sample OMF Supporting Data Table

Table A-X. OMF Supporting Data					
Date	**System**	**Issue**	**HW/SW**	**CMT (hh:mm)**	**Blue Sheet**
11/17/15	EO/IR	Power cycle	SW	00:02	Note 1
11/17/15	Display	Screen deformed	HW	00:24	Note 2
11/17/15	Hydraulic	Left main mount leak	HW	02:37	012
1. Single event observed in 272.4 operating hours. 2. Installed screen exceeded operating hour design specification by over 40 percent.					

Paragraph 2 of the Blue Sheet should focus on explaining how the OMF was detected and the impact upon the task, function, or mission. If the OMF occurred during a mission, discuss whether the OMF resulted in a mission abort, or whether the mission was able to continue after repair or restoration. Do not discuss the details of repairing/restoring the failure. If there was a problem conducting the maintenance actions, there should be a related Maintainability Blue Sheet where those issues are described. Similarly, if the repair/restoration was delayed excessively by parts, there should be a related Logistic Supportability (off-board delay) or Maintainability (onboard delay) Blue Sheet.

When grouping multiple OMFs into a single Blue Sheet, consider common characteristics that, when corrected, will resolve the issue. The way in which they are grouped can have a great effect on the ability to conduct a Verification of Correction of Deficiency (VCD) of the issue in future tests. Ensure HW and SW issues are not grouped together. When grouping, consider specific failure modes, similar characteristics, common conditions, etc. The goal should be to provide useful information to the program office to address specific issues that require correction.

2.3.1 Validating the Correction of Deficiencies

Many things should be considered when identifying a reliability issue (risk or deficiency). One of these must be, “what will it take to verify the issue has been corrected?” Reliability Blue Sheets should be written in a manner enabling them to be verified and validated as corrected. If a Blue Sheet is written for a one-time failure (in which a systemic issue was not established), consider what it would take to prove that failure has been corrected. Is there sufficient operating time planned during the VCD test? If there is no consideration whether a failure was systemic in the original test, nor any consideration how much operating time is needed during the VCD to prove the issue is no longer present, then both tests are flawed and credibility is diminished.

For every VCD, the test plan must clearly articulate:

- The root cause of the original problem,
- The corrective action taken to fix it,
- What the program office did to demonstrate the issue was corrected,
- A description of how the fix will be validated.

This is required for both stand-alone VCD test plans and VCDs as part of a Follow-on Test and Evaluation (FOT&E) phase (i.e., included in the FOT&E test plan).

2.4 MEASURES

Reliability measures are needed to help in understanding whether SUT reliability will support mission accomplishment. As stated earlier, Reliability is the probability the SUT will perform without failure over a specified interval under specified conditions. The following measures are designed to help determine that probability.

2.4.1 Required Measures

All operational tests must report a measure of Reliability, regardless of whether a threshold has been specified in requirements documentation. Where none are specified, the test team must determine what level of reliability is sufficient. However, even when a threshold is specified, the test team must still evaluate whether the observed result supports mission accomplishment. This must be done whether or not it met the threshold. The question that must be answered is this: "How reliable must the SUT be to support mission accomplishment?" The answer is not "reliable enough to meet the threshold." If designed for reliability, the threshold should support mission requirements. However, this is not always the case, especially when systems are designed for Availability, vice Reliability. The test team must answer this "so what?" question.

Having established that Reliability must be measured in all tests, regardless of the existence of specified requirements, and the resolution of Reliability cannot be solely based on threshold performance, the test team must decide which measure(s) to select. These decisions should be based on the duty cycle of the SUT and/or subsystem(s) being evaluated. The following discussion of measures should be used in conjunction with Appendix A of this handbook, which includes specific Data Requirements (DR) for each measure.

2.4.1.1 Continuously-operated and Intermittent-use Systems

<u>Mean Time Between Operational Mission Failure (MTBOMF)</u>
For *continuously-operated* and *intermittent-use systems*, Reliability should be measured relative to time. In both cases, the interest is in how likely the SUT will operate for a period of time without experiencing a critical failure. This can be done by measuring the MTBOMF (formula 2-1), which includes Mission Reliability (R) (formula 2-2), and MTBEFF when required. This measure shall be critical.

$$MTBOMF = \frac{Total\ System\ Operating\ Time}{Number\ of\ OMFs} \qquad \text{(Formula 2-1)}$$

Note 1: MTBEFF should also be used when conditional OMF scoring exists.
Note 2: If there are no OMFs, report “0 OMFs in [SOT] hours” as the measure result in the Data Analysis Summary (DAS) and Test Report (Major Quantitative Results), as appropriate.

It should be noted, that “time” must be expressed in mission-relevant units of measure (e.g., hours, rounds, cycles, miles, events, etc.). It does not need to tie exclusively to “clock time.” Using the most appropriate unit of measure is essential to ensure the measure of reliability is meaningful and mission relatable. For example, if the system being tested is an MV-22 Ramp Mounted Weapon System (RMWS), it might be more appropriate to measure Mean Rounds Between Operational Mission Failure (MRBOMF) instead of MTBOMF. This is because it would be more meaningful to understand the rate of failure with respect to the number of times the weapon cycles to load a round, fire it, and discard the empty cartridge.

When MTBOMF is measured, *Mission Reliability* (formula 2-2) should be calculated as part of the post-test analysis. It is not a separate measure. It is instead a separate calculation (or set of calculations) that helps provide understanding to the mission impact of the MTBOMF result. Formally defined, it is “a probability function, based on the actual physical components in the design, and how often they randomly fail during a fixed time period”[14]. In other words, Mission Reliability is the probability the SUT will not experience a failure during a specified interval. Although MTBF can also be used as an input, it is common to use observed MTBOMF and a mission time (t). Alternate expressions of Time may be used, as discussed above. If alternate expressions of time are used, it is critically important the unit of “time” is consistent between “t” and MTBOMF (e.g., t = number of rounds fired, and failure rate = Mean Rounds Between Failure). Note, “t” is not the mission time observed during test. It is an operationally representative time during which the SUT will be expected to conduct a mission in the Fleet. It is either the specified *Design Reference Mission Profile (DRMP) time*[15] or, where one does not exist, a time determined by the test team, based on SUT CONOPS. In some cases, there may be multiple mission times (associated with various mission sets), for which R can be calculated and reported based on the observed MTBOMF. The mission time(s) to be used should be determined during IEF development.

$$R = e^{\left(\frac{-t}{MTBOMF}\right)} \qquad \text{(Formula 2-2)}$$

Note 1: Calculate R based on MTBEFF when conditional OMF scoring exists.
(The “EXP” function in Excel may be used to calculate R)
Note 2: R_{HW} and R_{SW} can also be calculated based on $MTBOMF_{HW}$ and $MTBOMF_{SW}$, respectively.

Even if the capability requirements document does not specify a threshold for R, consideration should be given to reporting it because, given a validated operationally representative time “t,” it can be more meaningful than MTBOMF in assessing SUT reliability. A range of values, with associated confidence intervals, may be reported, if there exist multiple times associated with various mission sets. This is

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[14] OPNAVINST 3000.12A, Operational Availability of Equipment and Systems, 02 September 2003.
[15] A Design Reference Mission Profile (DRMP) is a mission profile that a SUT must be capable of supporting. This includes the mission type, conditions, duration, etc. Per OPNAVINST 3000.12A, “The DRMP provides a time history of events, functions (often referred to as use or operations) and environmental conditions that a system is expected to encounter during its life cycle, from manufacturing to removal from service use.”

because MTBOMF is merely a measure of how often a system failed during testing. If assumptions are validated, it should indicate what Fleet users should expect when employing the system in an operational environment. While determining MTBOMF is necessary in assessing reliability, it falls short of providing a result that is mission relatable. Mission Reliability translates this failure rate result into mission context.

For example, the SUT operated for 500 operating hours during the test phase and experienced 20 OMFs, resulting in a MTBOMF of 25 hours (500 / 20 = 25). Does this result support mission accomplishment? One could compare this value to a specified DRMP time (e.g., 10 hours). Although 25 hours, being greater than 10 hours, appears to be a good thing, it does not provide an indication of the chances of an OMF occurring during that time. Calculating Mission Reliability quantifies this chance.

$$R = e^{\left(\frac{-10}{25}\right)} = 0.67$$

One can see now, although the MTBOMF result is well above the required mission time, there is a 0.67 probability of executing that mission without an OMF. This provides a more mission relatable result to support the Reliability assessment.

Mean Flight Hours Between Operational Mission Failure (MFHBOMF)
For aviation systems, SOT is expressed typically in flight hours. MFHBOMF (formula 2-3) may be used in lieu of MTBOMF as the primary quantitative measure of Reliability.

$$MFHBOMF = \frac{Total\ Flight\ Hours}{Number\ of\ OMFs} \qquad \text{(Formula 2-3)}$$

Note: MFHBEFF should also be used when conditional OMF scoring exists.

Total SOT includes only the time the system is operating and being stressed under operational loads. However, critical failures can sometimes occur outside normal operating time for intermittent use systems (e.g., during standby time, while energizing the SUT during performance of corrective or preventive maintenance on other subsystems, etc.). During these times, the system is energized. Though it is operating at less than a full operational load, failures that would prevent the SUT from performing one or more mission essential functions must be recorded. These critical failures will be considered OMFs (or EFFs if conditional scoring is required) and used in the calculation of MFHBOMF (or MFHBEFF as appropriate). Note, these failures will be included in the calculation even if they did not occur during the hours totaled in the numerator. It is important to accurately characterize the rate of failure of the SUT relative to the defined SOT, which in this case is flight hours.

Because many SUTs have both HW and SW components (i.e., software-intensive systems), MTBOMF should be reported with respect to each: $MTBOMF_{HW}$ (formula 2-4) for HW failures and $MTBOMF_{SW}$ (formula 2-5) for SW faults. **$MTBOMF_{SYS}$ (formula 2-6), which combines both into one measure, should only be used when it is specified in the requirements document**.

$$MTBOMF_{HW} = \frac{Total\ System\ Operating\ Time}{Number\ of\ HW\ OMFs} \qquad \text{(Formula 2-4)}$$

Note: $MTBEFF_{HW}$ should also be used when conditional OMF scoring exists.

$$MTBOMF_{SW} = \frac{Total\ System\ Operating\ Time}{Number\ of\ SW\ OMFs} \qquad \text{(Formula 2-5)}$$

Note: $MTBEFF_{SW}$ should also be used when conditional OMF scoring exists.

$$MTBOMF_{SYS} = \frac{Total\ System\ Operating\ Time}{Number\ of\ HW\ and\ SW\ OMFs} \qquad \text{(Formula 2-6)}$$

Note: $MTBEFF_{SYS}$ should NOT be used when conditional OMF scoring exists because combined HW and SW Reliability measures should only be reported when specified.

It is important to separate $MTBOMF_{HW}$ and $MTBOMF_{SW}$, as HW failures and SW faults typically are distributed differently, due to different rates of failure. It is sometimes difficult to distinguish between a HW failure and a SW fault. It is recommended to use the following as a general rule. If the SUT functionality is restored via HW manipulation (e.g., replacing HW components), consideration should be given to scoring it as a HW failure; otherwise, score it as a SW fault. Work closely with your Lead Test Engineer (LTE), 01B, and 01C representatives during the MBTD and test planning processes to determine the appropriate reliability measure(s) for the SUT. This may include establishing and/or elevating $MTBOMF_{HW}$ and $MTBOMF_{SW}$ as critical measures, while evaluating $MTBOMF_{SYS}$ as a non-critical measure even though it may have a specified threshold. If conditional scoring is specified and EFF-based measures are used, avoid using $MTBEFF_{SYS}$/$MFHBEFF_{SYS}$, as a system-level reliability measure should be used only when specified in the requirements document.

2.4.1.2 On-demand and Impulse Systems

For on-demand or impulse systems, where time is not of primary concern or cannot be captured reasonably, one should measure Reliability on a mission or demand level (formula 2-7). If Reliability is to be measured on a mission level, it should be clearly understood when the mission begins and ends. This must be defined precisely in the IEF and test plan.

$$R = \frac{Number\ of Missions\ without\ an\ OMF}{Total\ Number\ of\ Missions} \qquad \text{(Formula 2-7)}$$

Note: EFFs should also be used when conditional OMF scoring exists.

Although sizing tests for Reliability is typically not done, it is worth noting it is more challenging to achieve sufficient levels of confidence when measuring reliability of on-demand or impulse systems. Essentially, more events would be needed in a binomial test, such as this, than in a test that measures Reliability on a continuous level, in order to have similar levels of statistical confidence. On occasion, the term Mission Completion Rate (MCR) is found in requirements documents and will need be addressed as a measure. MCR is rarely used (often only to answer specified requirements). The formula for MCR is synonymous with the formula for R.

2.4.2 Other Measures

MTBF

Similar to MTBOMF (formula 2-1), Mean Time Between Failures (MTBF) (formula 2-8) measures the average time between all failures, regardless of their criticality. It can be used if needed to characterize the overall likelihood of failure.

$$MTBF = \frac{Total\ System\ Operating\ Time}{Number\ of\ Failures} \qquad \text{(Formula 2-8)}$$

Note: This should be measured relative to HW failures or SW faults. Avoid measuring $MTBF_{SYS}$.

It can be especially useful in calculating Mission Reliability (R) for redundant systems, by providing for measurements of subsystem reliability.

> *For example, the SUT is a system with parallel-redundant subcomponents. In this example, only one of three subsystems is required to be operable for the system to operate. During testing, no more than two of the subsystems failed at any one time. Therefore, an OMF did not occur. Mission Reliability cannot be determined using MTBOMF (as in formula 2-1), as there were no OMFs, and MTBOMF cannot be calculated. Although an OMF was not experienced in testing, there exists a chance at some point in the future; all three may fail at the same time, causing an OMF. Instead, Mission Reliability should be calculated using a parallel redundancy equation (formula 2-10) based on subsystems MTBF (formula 2-9).*

$$R_{X,Y,Z} = e^{\left(\frac{-t_{x,y,z}}{MTBF}\right)} \qquad \text{(Formula 2-9)}$$

Note: X, Y, and Z represent various subsystems.

$$R_{SUT} = 1 - (1 - R_X) * (1 - R_Y) * (1 - R_Z) \qquad \text{(Formula 2-10)}$$

<u>$MTBOMF_{MA}/R_{MA}$</u>

It is highly encouraged to measure and report Reliability with respect to specific mission areas (formula 2-12) for multi-mission systems. These formulae are essentially the same as formulae 2-1, 2-2, and 2-3 above. However, SOT and OMFs are considered only with respect to the mission area being evaluated.

$$MTBOMF_{MA} = \frac{Total\ [MA]\ System\ Operating\ Time}{Number\ of\ [MA]\ OMFs} \qquad \text{(Formula 2-11)}$$

$$R_{MA} = e^{\left(\frac{-t_{MA}}{MTBOMF_{MA}}\right)} \qquad \text{(Formula 2-12)}$$

Note: Replace "MA" with the mission area abbreviation (e.g., AW, ASW, etc.)

This can (and should) be done in conjunction with reporting Mission Capable by Mission Area (MC_{MA}) as discussed in chapter 5 (Availability) section 5.3.1.1.

<u>Mean Time Between Unscheduled Maintenance/Mean Flight Hours Between Unscheduled Maintenance (MTBUM/MFHBUM)</u>

MTBUM/MFHBUM (formula 2-13) is fundamentally no different than MTBF. Yet, Reliability requirements are sometimes expressed using this measure for aviation systems. This measure should be reported only when a threshold exists.

$$MTBUM/MFHBUM = \frac{Total\ System\ Operating\ Time\ (Flight\ Hours)}{Number\ of\ Unscheduled\ Maintenance\ Actions} \qquad \text{(Formula 2-13)}$$

Mean Time Between Aborts/Mean Flight Hours Between Aborts (MTBA/MFHBA)
MTBA/MFHBA (formula 2-14) is often used in aircraft requirements documents. It is similar to MTBOMF/MFHBOMF, in that OMFs are used. However, the OMFs must result in a mission abort.

$$MTBA/MFHBA = \frac{Total\ System\ Operating\ Time\ (Flight\ Hours)}{Number\ of\ Mission\ Aborts} \qquad \text{(Formula 2-14)}$$

2.4.3 Calculating Reliability in Series/Parallel Systems

Some reliability models merely calculate system reliability based on given component reliabilities. The reliability of sub components in parallel (the system fails if all components fail) is provided above in formula 2-10. The reliability of sub components in series (i.e., if any component fails the system fails) is the product of the component reliabilities (formula 2-15)

$$R_{SUT} = R_X * R_Y * R_Z \qquad \text{(Formula 2-15)}$$

Note: X, Y, and Z represent various subsystems.

When there are many components arranged in a complex manner, the math can be tedious. A computer program is a good way to solve the problem. If enough good component data are available, component failures are independent, and component reliabilities will be the same in the system, then the results of such calculations are not only good, they are a mathematical certainty. These calculations can be used to calculate overall reliability; or given the overall reliability, calculate component reliabilities.

Subcomponent reliability values will typically be the average value of the individual subcomponents. This is a conservative approach, which will result in a lower SUT reliability value. There are cases, where the individual vice average subcomponent reliability is used, and thus should be identified in the IEF and test plan.

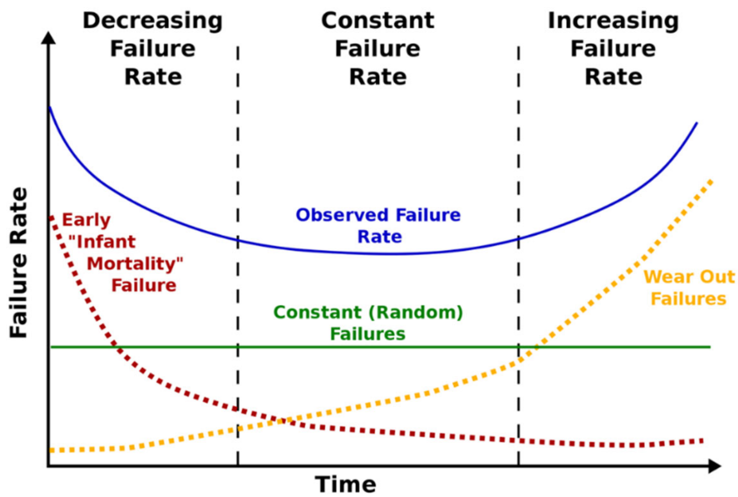
Calculating R this way may not be necessary when each subcomponent has the same duty cycle. In which case, one could just measure it as a complete system. However, if for example subcomponents X and Z are on-demand subsystems and subcomponent Y is intermittent-use; calculating it this way would be necessary because the reliability of X and Z would be measured differently than Y. This can be particularly useful, when one cannot test the system with X, Y, and Z available all the time, due to constraints other than system reliability failures, or when timing of failures in each of the subcomponents do not result in OMFs during relatively short test times.

2.4.4 Assumptions

For these reliability measurements to be meaningful, to both Fleet users and system developers, a number of assumptions must be made. These assumptions may or may not be true. This depends on the unique attributes of the system, and where the program is currently in its life cycle. Each of these can, and should be verified during post-test Exploratory Data Analysis (EDA). When proven false, the results should be presented in a way that represents most meaningfully the characteristics of the data.

Constant Failure Rate
An underlying assumption for the vast majority of systems is the mean HW failure rate is constant. The "bathtub" curve for failure rates illustrates the assumption the system is past the break-in (or "infant mortality") stage, but has not yet reached the wear-out stage (see figure 2-3).

Figure 2-3. Failure Rate Bathtub Curve



Initial Operational Test and Evaluation (IOT&E)/FOT&E should normally take place near the center part of the graph, where the failure rate is relatively constant. However, this is not always the case. For example, a system might still be in the infant mortality phase if the system configuration is in flux. It is important to understand how stable the SUT configuration is, or is planned to be, by the start of OT. If the constant failure rate assumption is violated seriously, the MTBOMF measure is not appropriate. For the same reason, Mission Reliability (R), as calculated in formula 2-2, is not a meaningful predictor of reliability, without a correction factor applied that accounts for the non-steady state failure rate. (It is not reasonable to assume that sufficient data will be obtained during test to determine this factor.) Instead, failure data should be reported in a way that best describes system reliability characteristics and represents the observed distribution. See section 2.7, *Reliability Data Analysis*, below.

<u>MTBOMF data contains exponentially distributed failure times</u>
Since one assumes the system is being tested in the useful life period of the bathtub curve, the observed failure rate should be driven primarily by randomness. This means it is assumed MTBOMF data contain exponentially distributed failure times. It also means the chance of failure in 1-hour of testing is the same, regardless of when the hour occurred. Failures occur regardless of how long the system has been in test (i.e., the system has no "memory"). As the system is tested, each HW failure is repaired and the test continues. After each repair, the system is considered "as good as new," as opposed to being considered a different system.

If post-test analysis reveals the failure data are not exponentially distributed, then R (formula 2-2) may not be appropriate, and the likelihood of failure-free performance should be estimated another way.

<u>All test articles have the same reliability characteristics</u>
Based on the previous assumption, given multiple units of the same system, all have the same underlying failure rate. There should be no difference between testing 10 systems for 100 hours, and testing one system for 1000 hours. Ideally, since the main driver of the HW failures should be

randomness, time on a particular SUT should not influence failure rate.

Conditional scoring of failures can harm these assumptions. An underlying principle in each of them is the idea that randomness is the primary driver on the observed HW failure rate. Conditional scoring permits certain failures to be removed from the test sample, potentially removing randomness as being the driver of failure rate. Therefore, not only does it potentially invalidate the exponential distribution assumption, it no longer represents the rate at which Fleet users should expect to see failures when operating the system.

2.4.5 Practical Trade-offs

Although the assumption is the SUT is operating in the bottom of the bathtub curve, and randomness should be what primarily drives the occurrence of HW failures; this is not always true. Failures can be due to many factors, including system design, quality assurance, installation, personnel, transportation, or unknown (other random) reasons.

Although typically there exists an inability to influence the number of available test articles for continuous- or intermittent-use SUTs, one should consider each of these factors in turn to determine their impact on testing one or many systems. If a failure occurs as a result of a design flaw, the same flaw is present in each system. Therefore, testing only one system or testing several systems makes no difference. If a failure occurs due to poor quality assurance, it would be preferable to have several SUTs, rather than just one. If limited testing to only one system, one might select a "lemon" or a "perfect" system, which would result in misleading conclusions. The preference would be to average out this phenomenon, as one would in Fleet use. The same is true of failures due to installation, personnel, transportation, or random factors. The more SUTs, the better to mitigate performance of outliers (i.e., "lemons" or "perfect" systems).

However, there is a potential trade-off. Testing many items for short periods may miss important failure modes. For example, if there is a design flaw in a system that typically causes failures to occur after 800 operating hours, then testing eight systems for 100 hours may not uncover this failure mode. Although this failure reveals a possible flaw in our reliability assumptions (i.e., infant mortality failure mode), it is a realistic situation that occurs in operational testing. Early involvement observations of system performance and system Subject Matter Experts (SME) are resources for this type of test time/duration risk assessment.

2.5 SAMPLE SIZE AND TEST LIMITATIONS

OT duration is scoped primarily by the data and resource requirements needed to resolve Effectiveness COIs. In an ideal world, the MBTD process, used to scope the effectiveness side of the test, would result in a sufficient level of data to support the Suitability evaluation as well. This is not always the case. The question of how much data are needed centers on Reliability. Resolving Reliability is determined through analysis of the critical reliability threshold (i.e., MTBOMF or R).

Two considerations go into this analysis: planned SOT and the expected number of OMFs. At OPTEVFOR, a rule of thumb is used for continuous- and intermittent-use SUTs[17]. Assuming an exponential or Poisson distribution of failures, 80 percent confidence in the test results, planned test time equal to three times the MTBOMF threshold (or the MTBOMF value corresponding to the R threshold), and only one failure, the 80 percent one-sided Lower Confidence Limit (LCL) will be at the threshold. If one considers most systems are designed to near threshold, approximately three failures should be expected. (The Poisson distribution is also related closely to the exponential, in that the "inter-arrival" times of the events in a Poisson process are exponentially distributed.) This time is used as the basis of the general rule of thumb to determine how much test time is required to demonstrate a reliability threshold. If the test size, initially determined through MBTD, is insufficient, additional resources can be requested to ensure Reliability can be resolved (or assessed).

Table 2-2 displays the rule of thumb, for continuous-use and intermittent-use systems, and how it relates to pre-test limitations to test, used in IEF and test planning.

Table 2-2. Reliability Limitations to Test Rule of Thumb

Planned[18] SOT	Limitation to Test
Greater than 300% MTBOMF Threshold	None
100-300% MTBOMF Threshold	Minor[1]
50-100% MTBOMF Threshold	Major[2]
Less than 50% MTBOMF Threshold	Severe[3]

Notes:
1. Minor - Minimal impact on COI assessment or resolution and do not impact the ability to form conclusions regarding Suitability.
2. Major - May affect COI assessment or resolution but should not impact the ability to form conclusions regarding Suitability.
3. Severe - Precludes COI assessment or resolution and adversely impact the ability to form conclusions regarding Suitability.

For on-demand or impulse SUTs, there is no rule of thumb. Adequacy should be determined by first determining the number of test/demonstrations needed to evaluate effectiveness COIs. That result then should be evaluated using an estimated binomial two-sided confidence interval. One might consider recommending increasing the size of the test to achieve a desired precision in the interval.

For systems with high MTBOMF thresholds, the time available to conduct OT&E may not be sufficient to meet this criterion. For some test phases (especially in FOT&E), there may be additional sources of data available to augment test results, allowing resolution of the reliability COI despite the planned shortfall. These include data from Fleet use of the SUT, data from previous phases of Developmental Testing (DT)/OT, and data from similar systems (e.g., common hardware components) to the one being tested. In reality, there may not be enough funding or test time to get sufficient SOT. However, the program

[17] This rule of thumb cannot be used for Impulse systems. Test size should be analyzed using confidence for a binomial measurement of Reliability.
[18] It should be noted this rule of thumb only applies in planning. Actual OT data must be used to determine if a limitation to test was actually experienced during testing.

office's funding or schedule should not drive the OT time to the point where there is little or no confidence that the test results are true representations of the system in Fleet use.

In cases when a severe limitation to test is anticipated, and all other potential sources of additional data have been exhausted, additional resources should be requested. Recommending FOT&E, just to resolve reliability, would be expensive and time-consuming. Planning for alternate Reliability data sources to augment OT should be conducted at the earliest possible opportunity. For example, when using Fleet data to augment test results, a ship's schedule may dictate such a data collection process start prior to the commencement of an OT event. The test team must plan in advance exactly which data are required, and how they must be collected. The IEF and test plan should reflect this determination.

2.6 ADDITIONAL DATA SOURCES

OPTEVFOR has historically faced challenges in testing acquisition programs with high reliability requirements and limited test resources. Some newer acquisition programs are being developed to meet threshold reliability hours that exceed 2,500 hours. For such a system, 7,500 hours of testing (approximately 300 days) is required to test that a typical SUT meets its reliability threshold with 80 percent confidence (assuming one fault/failure during test). Tests with SUTs possessing high reliability requirements, short mission durations, and/or limited resources, should supplement OT data with OT-qualified Fleet suitability data or DT data qualified for OT use. When identifying risk, as during an Operational Assessment (OA) or Early Operational Assessment (EOA), data on similar systems or models can be used following favorable comparison to the tested SUT.

2.6.1 Available Fleet Data

If the Fleet is using the system, and reliability data are available, this is the best source of information to augment test results. This may occur if system installation was complicated, and uninstallation between test phases is impractical; or the system is fielded, even if in limited numbers, concurrently (or near concurrently) with OT. Using Fleet data requires specific planning and active involvement in data collection to ensure they can be qualified for use in OT. Chapter 6 provides specific guidance on gathering Fleet suitability data.

2.6.2 Previous Phases of OT/DT

Reliability data from previous phases of DT and OT can provide excellent indicators and disclose possible trends in system reliability, if the system has not changed substantially from one test phase to the other. These data from earlier testing may provide a good indicator of reliability trends in system development. In this case, there would be less stringent requirements on the pedigree of the data collected to leverage it for use in understanding trends and system usage. On the other hand, it may be possible to use earlier test results to augment IOT&E or FOT&E results directly, if there have been no significant changes in system design affecting reliability, and the testing was conducted under realistic operational conditions. In addition, the data collection and measurement parameters methods must be the same for both test phases. If data from DT are to be qualified as OT data each of the following criteria should be met:

- The system under test during OT is not significantly different than that which was tested during previous test periods.
- The SUT was tested in operationally representative operational tempo.

- The SUT was tested using operationally representative, qualified, and proficient operators and/or maintainers.
- The SUT was tested in an operationally representative environment.

Any differences, with respect to DT and OT, must be understood clearly and analyzed to determine if they are significant enough to disqualify the data. For systems with very high reliability requirements (requiring very long test times), limited test opportunities, or unreasonably high resources requirements, using DT data may be critical to the evaluation strategy. In these cases, the differences with respect to each of the above four criteria must be clearly understood and discussed in the test report.

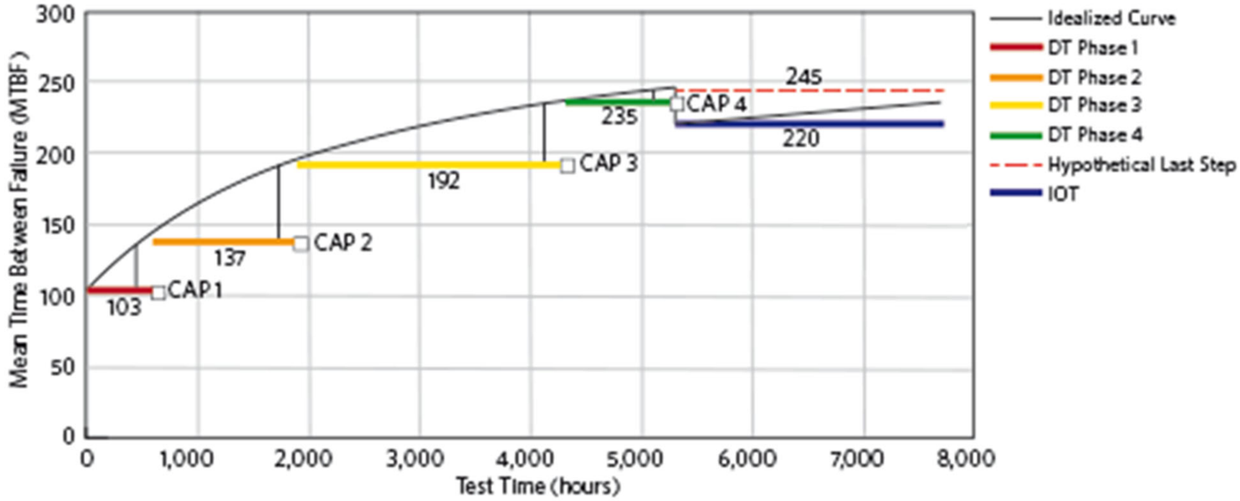
2.6.3 Data on Similar Systems

As with data from previous test phases, data on similar systems can be used as an indicator of new system reliability. This could be useful during an OA/EOA in assessing risk to successful Reliability performance at IOT&E/FOT&E. Data from similar systems has the potential to augment OT data with respect to specific subsystems. For example, consider a 57 mm gun, previously integrated and tested on the National Security Cutter (NSC), now being installed on a variant of the Littoral Combat Ship (LCS). The SUT will likely have undergone modifications to integrate it onto the LCS. However, there should be significant areas of commonality to support using previous test data to support assessing risk to integration on LCS. On the other hand, the impact of interoperability differences may not be accounted for between the two systems (e.g., different structural loads, vibration, thermal cycling, power quality, cooling/ventilation, and other characteristics between the install on one ship and the other). These differences could result in differences in failure rate. In addition, determining whole system reliability may not be possible, because only certain subsystems or components may be common between the SUT and the system to which it is being compared. Using data on similar systems is most applicable to OAs, in which risks to reliability of the system are identified.

2.6.4 Reliability Growth Models

Over time, most systems under development exhibit reliability growth. System reliability changes as a result of configuration changes. Reliability growth models aim to predict these improvements. This method does not measure the true reliability of a system, but is a model of the development process. These models may be of interest early in the development process to help assess program risk. However, they should not be expected to provide sufficient information to support resolution of the reliability COI. They can, however, aid in assessing risk to the COI during an EOA or OA. If this type of model is going to be used, the program's plan for growth must be clearly understood. For a system to experience reliability growth, it must undergo periods where improvements to system design are made. These improvements occur during Corrective Action Periods (CAP). Without these, there can be no growth, if one assumes failures are driven primarily by random effects. Figure 2-4 shows an Example Reliability Growth Curve, which depicts the projection of MTBF, relative to the total cumulative test time since system development began. In it, key measurements of MTBF are indicated along with the CAPs. One can use a curve like this to compare MTBF (or MTBOMF) measured during an OA or EOA, to where it should be on the reliability growth plan. If it is currently above the curve, and the upcoming CAPs are realistic; then one might say, although current measured reliability is below the requirement, there is a low risk to it meeting the requirement at IOT&E. Therefore, an understanding of the CAPs is critically important to using growth. If there is insufficient time to correct system reliability, or if the program does not intend to execute planned CAPs before IOT&E, this tool is not useful in assessing risk.

Figure 2-4. Example Reliability Growth Curve



2.7 RELIABILITY DATA ANALYSIS

One should not wait until the end of a test phase to explore the data and begin analyzing measure results. Reliability Data Analysis should begin during testing, as important things can be learned by exploring data, while collection is ongoing. In addition to getting a head start on the Data Analysis Summary, the test team can start identifying trends in performance, uncovering dominant failure modes, and exploring issues requiring investigation, while still having access to the system.

2.7.1 Exploratory Data Analysis (EDA)

The Reliability Data Analysis Process should begin with EDA. One should not simply insert the totals for SOT and failures blindly into the respective formulae, and put them in the Data Analysis Summary, without considering what the data says. A number of assumptions were made when the measures were chosen, whether they were consciously chosen or not. These assumptions must be validated to ensure the planned formulae can be used, and the measures hold the meaning they were intended to hold. If not, or if an initial inspection of the data reveals something of interest, alternative forms of presentation should also be used. This is revealed through EDA. After inspecting the data for assumption validation, trends, dominant failure modes, etc., one can then develop a strategy of data presentation.

Any one of a number of methods can be used in this process. It warrants additional emphasis there is no need to wait until testing is completed and all data have been scored to begin this process. In addition to methods described in the OT Analysis Handbook, table 2-3 includes a number of graphical analysis tools, useful in performing this exploration. Each of these is useful in helping describe the data, identifying trends, and validating assumptions.

Table 2-3. Exploratory Data Analysis (EDA) Tools

Technique	Considerations
Box Plot	• Used to graphically depict groups of numerical data non-parametrically through their quartiles • Useful in displaying degree of dispersion of data and skewness
Histogram	• Can be used to accurately represent the distribution of data • Displays an estimate of the probability distribution

Table 2-3. Exploratory Data Analysis (EDA) Tools	
Technique	**Considerations**
	• Different from a bar graph in that it relates only one variable and displays data continuously
Run Chart	• Displays data in a time sequence, usually representing the output of a process • Helpful in identifying outliers
Pareto Chart	• Used to highlight the most important (or frequent) among a set of factors • Useful in identifying dominant failure modes
Scatter Plot	• Displays values for two variables (typically) • Additional variables can be displayed using color-coding

Some of these techniques are used in the examples in section 2.8 below.

2.7.2 Reliability Data Statistics

As discussed in the previous section, tests are not designed using a deliberate analysis of power and confidence for reliability data. As such, two-sided confidence intervals are neither used in scoping planned testing, nor used in reporting test results. They can, however, be used during post-test analysis to compare various sets of data. This may include comparing OT data collected during different test periods or data collected from alternate sources.

Alternate sources include data from Fleet use of the system, DT, Integrated Test (IT) periods, and/or previous phases of OT. There are various statistical methodologies that can be applied to alternative sources of data, which give the OTD a clearer picture of the added value of such information. For example, to determine whether reliability results, obtained during the current phase of OT, are comparable to those obtained for a previous phase of OT; hypothesis testing could be used to compare the two OT MTBOMFs. Alternately, two-sided confidence intervals could be constructed around the two MTBOMF values to see if there is any overlap in values. If no overlap exists, it is not recommended to pool the different sets of data into a single set for the purpose of calculating measures with increased confidence. If an overlap does exist, it may indicate a statistically insignificant difference in the mean, median or applicable summary statistic, assuming the SUTs were similar enough and were operated in a similar manner and under similar conditions. However, pooling these data sets should be performed with caution.

If, through analysis of these other data, it is determined changes to system configuration were insignificant; it was operated and maintained by Fleet warfighters and maintainers; it was operated under similar conditions; and data were collected and scored the same across all phases, then one might combine the data. If the failure rates are very different, the test periods/phases should be evaluated separately. Configuration changes and differences in data collection/scoring will often be the main limiting factors. The following section provides tools to calculate two sided confidence intervals when desired to analyze data from different sources.

2.7.3 Calculating upper and lower one –sided confidence limits for MTBOMF[19]

Confidence bounds for the typical Type I censoring situation are obtained from chi-square distribution tables or programs. Type I censoring occurs when testing stops at a predetermined time as opposed to after a set number of failures. As discussed earlier in the chapter, this works for any life event unit (e.g., miles, cycles, rounds, etc.) as long as the units are used consistently. The formula for calculating two-sided confidence intervals is:

$$P\left[\frac{2T}{\chi^2_{1-\frac{\alpha}{2},2(r+1)}} \leq True\ MTBF \leq \frac{2T}{\chi^2_{\frac{\alpha}{2},2r}}\right] \geq 1-\alpha$$

In this formula, $\chi^2_{\frac{\alpha}{2},2r}$ is a value that the chi-square statistic with 2r degrees of freedom is less than with probability α/2. In other words, the left-hand tail of the distribution has probability α/2.

A one-sided, lower 100(1-α/2) percent confidence bound for the MTBF is given by:

$$LOWER\ CONFIDENCE\ LIMIT = \frac{2T}{\chi^2(1-\frac{\alpha}{2},2(r+1))}$$

Where T is the total unit or system test time, r is the total number of failures.

A one-sided, upper 100(1-α/2) percent confidence bound for the MTBF is given by

$$UPPER\ CONFIDENCE\ LIMIT = \frac{2T}{\chi^2(\frac{\alpha}{2},2r)}$$

The two limits together, (LOWER, UPPER), are a 100(1-α) percent two-sided confidence interval for the true MTBF.

In Microsoft ® Excel ® 2016, one should use the "CHISQ.INV" function to calculate the denominator.

<u>Example</u>:

A system was observed for 2 calendar months of operation, during which time it was in operation for 800 hours and had 2 failures. What are the 80 percent (α = 0.2) upper and lower one-sided confidence limits?

<u>Solution</u>:

$$LOWER = \frac{2T}{\chi^2((1-\frac{\alpha}{2}),2(r+1))} = \frac{2*800}{\chi^2((1-\frac{0.2}{2}),2*(2+1))} = \frac{1600}{\chi^2(0.90,6)}$$

[19]The following confidence interval/limit calculations are made using the chi-square distribution. Formulas and discussion derived from: https://www.itl.nist.gov/div898/handbook/apr/section4/apr451.htm#Calculation%20of%20Confidence.

$$UPPER = \frac{2T}{\chi^2(\frac{\alpha}{2},2r)} = \frac{2*800}{\chi^2(\frac{0.2}{2},2*2)} = \frac{1600}{\chi^2(0.10,4)}$$

Using Excel ® 2016:

	A	B	C	D	E
1					
2	**Total Operating Time:**	800			
3	**Number of Failures:**	2		Two-Sided	
4	**α:**	0.2		**Lower Limit**	**Upper Limit**
5	**MTBF/MTBOMF:**	**400**		**150.31**	**1504.29**

Lower Limit = (B2*2)/CHISQ.INV((1-B4/2),(2*(B3+1)))
Upper Limit = (B2*2)/CHISQ.INV((B4/2),(2*B3))

2.8 EXAMPLES

The following sections present several typical scenarios, and provide examples of applicable reliability data analysis.

2.8.1 Intermittent-Use Systems

Consider an intermittent-use SUT which is designed to operate for specific periods of time to support mission tasking. When not required, it is powered down until needed again. It is similar to a continuous-use system in that time matters, but periods of inactivity are permissible given its concept of operations. Therefore, SOT is tracked on an event level. Formulae 2-1 and 2-2 are used to characterize overall system reliability.

$$MTBOMF = \frac{Total\ System\ Operating\ Time}{Number\ of\ OMFs} \qquad \text{(Formula 2-1)}$$

$$R = e^{(\frac{-t}{MTBOMF})} \qquad \text{(Formula 2-2)}$$

Case 1 – How to calculate SUT reliability, based on the number of OMFs and SOT (one test article).

Given the data set in table 2-4, calculate the probability of completing a 3-hour mission without an OMF.

Table 2-4. MTBOMF Supporting Data

Date	Event #	SOT	OMF	Time to Failure
01/15/18	1	5:21		
01/26/18	2	0:00	Y	5:21
01/26/18	3	11:40		
01/26/18	4	11:34		

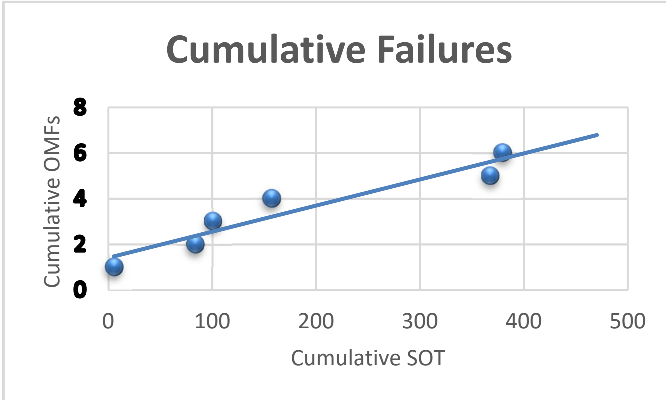
Table 2-4. MTBOMF Supporting Data				
Date	**Event #**	**SOT**	**OMF**	**Time to Failure**
01/27/18	5	12:31		
01/27/18	6	10:30		
01/28/18	7	11:31		
01/28/18	8	11:14		
01/29/18	9	9:17	Y	78:17
01/29/18	10	5:16		
01/29/18	11	7:09		
01/30/18	12	5:20	Y	17:45
01/30/18	13	4:24		
01/30/18	14	2:36		
02/01/18	15	15:50		
02/01/18	16	15:30		
02/03/18	17	17:15	Y	55:35
02/03/18	18	0:00		
02/03/18	19	17:15		
02/04/18	20	12:56		
02/04/18	21	8:15		
02/04/18	22	12:56		
02/05/18	23	13:04		
02/06/18	24	12:00		
02/06/18	25	12:00		
02/07/18	26	14:27		
02/10/18	27	14:37		
02/11/18	28	3:30		
02/11/18	29	90:10	Y	211:10
02/11/18	30	11:30	Y	11:30
06/09/18	31	21:36		
06/10/18	32	18:40		
06/11/18	33	18:30		
06/12/18	34	12:48		
06/13/18	35	9:24		
06/14/18	36	9:36		
	Total	470:12 (470.2 hrs)	6	

Solution:

First, perform some EDA to validate assumptions. As a reminder, these assumptions were:

1. Constant Failure Rate. It is assumed the rate of failure will remain relatively constant (or non-chaotic) during testing. This can be verified by plotting cumulative OMFs versus cumulative SOT. Figure 2-5 shows this assumption appears to be valid, given the sample data set.

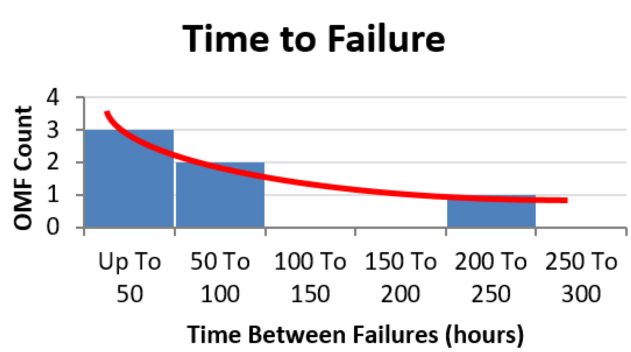
Figure 2-5. Constant Failure Rate Plot



Note: it is not always possible to observe enough failures to verify this assumption via a cumulative failure plot. It may be possible to obtain a report from the program manager on HW and SW changes over time, and then determine how stable the system is.

2. MTBOMF data contains exponentially distributed failure times. It is assumed the occurrence of OMFs will be random. Therefore, the distribution of time to failure will be exponential. Although figure 2-6 appears consistent with this assumption, the quantity of data may be insufficient to confirm it.

Figure 2-6. Distribution of Time to Failure



Excel ® or JMP ® may be used to plot this. However, if the test yields few failures, the test may lack the power needed to observe an exponential curve.

Next, with assumptions verified, MTBOMF and R can be calculated:

$$MTBOMF = \frac{470.2}{6} = 78.37\ hours \qquad \text{(Formula 2-1)}$$

$$R = e^{\left(\frac{-3}{78.4}\right)} = 0.962 \qquad \text{(Formula 2-2)}$$

Therefore, there is a 0.96 probability of completing a 3-hour mission without an OMF.

Case 2 – How to calculate SUT reliability based on the number of OMFs and SOT (multiple test articles).

Consider the data set presented in table 2-5, which includes reliability data from nine test articles used during OT. The table displays the OMF data with respect to each aircraft used during testing. Given this set, calculate the probability of completing a 3-hour mission without an OMF.

Table 2-5. MTBOMF Supporting Data (Data Set #2)

Aircraft Side Number	Flight Hours	OMFs (#)	MFHBOMF (hours)
102	64.0	8	8.0
104	106.0	2	53.0
200	80.0	2	40.0
212	54.0	6	9.0
214	38.0	2	19.0
301	39.0	3	13.0
305	35.0	6	5.8
308	156.0	26	6.0
401	50.0	1	50.0
Total	622.0	56	11.1

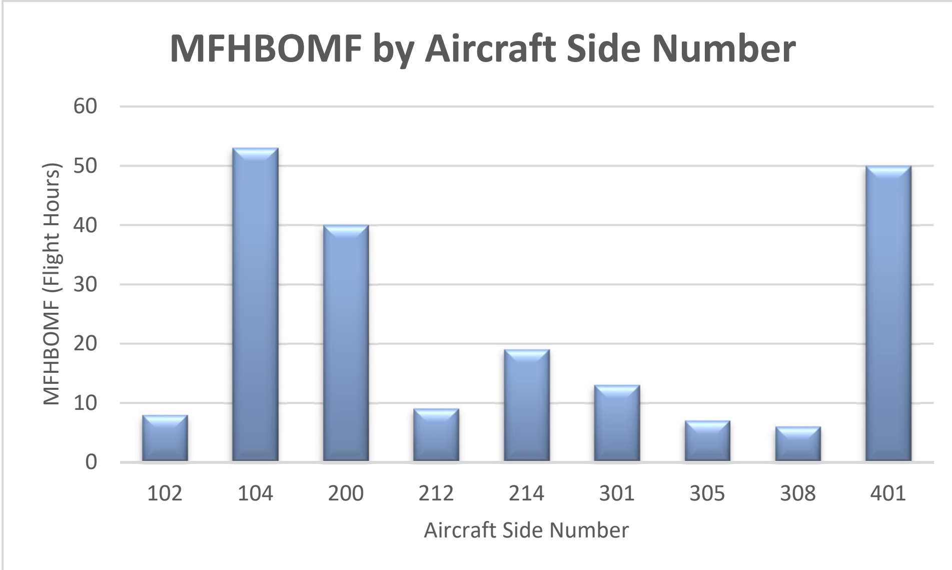
Solution:

First, explore the data to validate assumption. The same assumptions from case 1 apply.

MTBOMF data contains exponentially distributed failure times. It is assumed the occurrence of OMFs will be random. Therefore, the distribution of time to failure will be exponential. This assumption also implies the occurrence of failures does not depend on how long the system has been in test (i.e., the system has no "memory"), and given multiple units of the same system, all have the same underlying failure rate. This assumption can be disproven by demonstrating the data fail to meet either of those criteria.

Figure 2-7 (along with visual inspection of the data in table 2-5) shows this assumption appears invalid, given the sample data set. MFHBOMF results ranged from 6.0 to 53.0 flight hours. It is apparent something other than randomness is influencing the failure rate in this case. It is recommended to explore what other factors may be at play (e.g., aircraft age, mission types, environmental conditions, etc.). It appears aircraft side numbers 104, 200, and 401 could be treated as a separate group from the others.

Figure 2-7. MFHBOMF vs Aircraft Side Number



An overall MFHBOMF may still be reported (to answer specified requirements). However, the probability of completing a 3.0 flight hour mission cannot be calculated using the mission reliability formula. In addition, one should not necessarily create a two-sided confidence interval on MFHBOMF that rolls up hours from all aircraft because of these differences. A graphic, such as figure 2-7 along with other analytical tests, should be included in the Data Analysis Summary.

2.8.2 On-Demand System

Consider an on-demand SUT, which is designed to have relatively long periods of standby or inactivity between uses where time, or any measurement of system lifetime, does not matter (e.g., torpedo launcher) or is not practical to record. Reliability is tracked on an event (or demand) level. Formula 2-7 is used to characterize overall system reliability.

$$R = \frac{Number\ of\ Missions\ without\ an\ OMF}{Total\ Number\ of\ Missions} \qquad \text{(Formula 2-7)}$$

Calculate R, given the following data set (table 2-6).

Table 2-6. R Supporting Data Table (On-demand System)

Date	# of Attempts	OMF (Y/N)
1/15/2014	1	Y
1/26/2014	1	Y
	1	N
	1	N
1/27/2014	1	N
	1	N
1/28/2014	1	N
1/29/2014	1	N

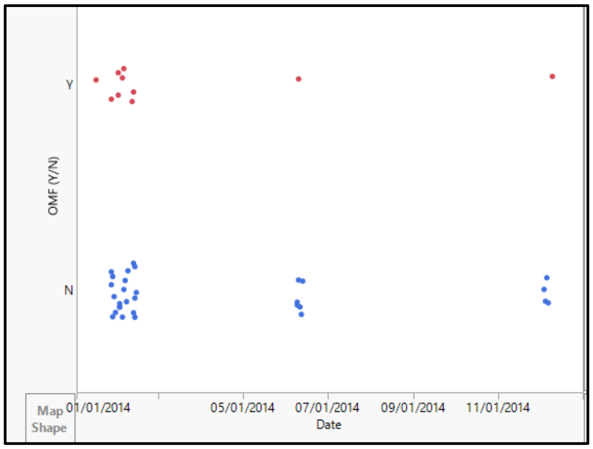
Table 2-6. R Supporting Data Table (On-demand System)		
Date	**# of Attempts**	**OMF (Y/N)**
1/31/2014	1	Y
1/31/2014	1	Y
2/1/2014	1	N
	1	N
	1	N
2/3/2014	1	Y
	1	N
2/4/2014	1	Y
	1	N
2/5/2014	1	N
2/6/2014	1	N
2/7/2014	1	N
2/10/2014	1	Y
2/11/2014	1	Y
	1	N
	1	N
2/12/2014	1	N
	1	N
	1	N
2/13/2014	1	N
6/9/2014	1	N
6/9/2014	1	N
6/10/2014	1	Y
6/10/2014	1	N
6/11/2014	1	N
6/12/2014	1	N
6/13/2014	1	N
12/4/2014	1	N
12/5/2014	1	N
12/6/2014	1	N
12/7/2014	1	N
12/10/2014	1	Y
Total	**40**	**30 (sorties without an OMF)**

Solution:

Verify assumptions:

Constant Failure Rate. The assumption is the rate of failure will remain relatively constant (or non-chaotic) during testing. This can be verified by plotting OMFs versus test time. Figure 2-8 shows this assumption appears valid, given the sample data set.

Figure 2-8. Failures vs Time



Next, with assumptions verified, R can be calculated:

$$R = \frac{30}{40} = 0.75 \qquad \text{(Formula 2-7)}$$

Based on these data, the probability of not experiencing an OMF during a mission is 0.75.

2.8.3 Series/Parallel Systems

For the following examples, the SUT consists of subcomponent X, subcomponent Y, and subcomponent Z. In all examples, take as true the assumptions of constant failure rate and/or exponential distribution of failure times.

Formula 2-7 is the basic equation used to calculate reliability.

$$R = \frac{Number\ of\ Missions\ without\ an\ OMF}{Total\ Number\ of\ Missions} \qquad \text{(Formula 2-7)}$$

Where R can be any of the following:

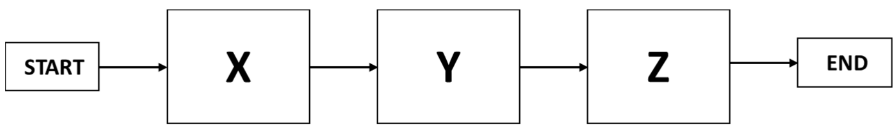
- R_{SUT} = Reliability of the SUT
- R_X = Reliability of subcomponent X
- R_Y = Reliability of subcomponent Y
- R_Z = Reliability of subcomponent Z

Case 1 – How to calculate SUT reliability based on the measured subcomponent reliability, if the subcomponents function in series for overall system operation.

R_{SUT} is the Reliability of subcomponent X and subcomponent Y and subcomponent Z functioning for overall system operation (Formula 2-15).

$$R_{SUT} = R_X * R_Y * R_Z \qquad \text{(Formula 2-15)}$$

Figure 2-9. SUT with Subcomponents in Series



Calculate overall system reliability, if subcomponent X has a reliability of 0.8, subcomponent Y has a reliability of 0.87, and subcomponent Z has a reliability of 0.6. If the SUT requires all three subcomponents to work, the subcomponents are in series.

Solution:
$R_{SUT} = R_X * R_Y * R_Z$

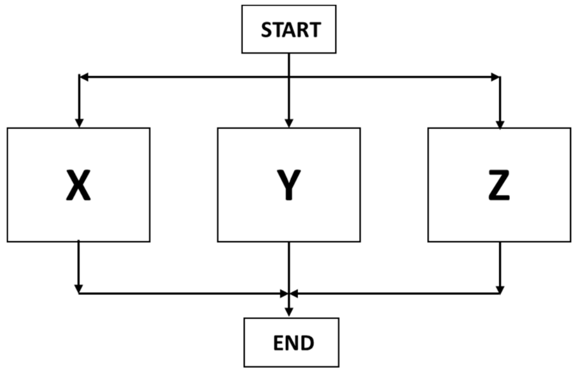
$$R_{SUT} = 0.80 * 0.87 * 0.60 = 0.42 \qquad \text{(Formula 2-15)}$$

Case 2 – How to calculate SUT reliability based on measured subcomponent reliability, if the SUT requires one out of three subcomponents to function for overall system operation (i.e., parallel system configuration).

R_{SUT} is the Reliability of subcomponent X or subcomponent Y or subcomponent Z functioning (Formula 2-10).

$$R_{SUT} = 1 - (1 - R_X) * (1 - R_Y) * (1 - R_Z) \qquad \text{(Formula 2-10)}$$

Figure 2-10. SUT with Subcomponents in Parallel (1 of 3 subcomponent required)



Calculate overall system reliability, if subcomponent X has a reliability of 0.8, subcomponent Y has a reliability of 0.87, and subcomponent Z has a reliability of 0.6. If the SUT requires one out of three subcomponents to work for overall system operation, the subcomponents are in parallel.

<u>Solution:</u>

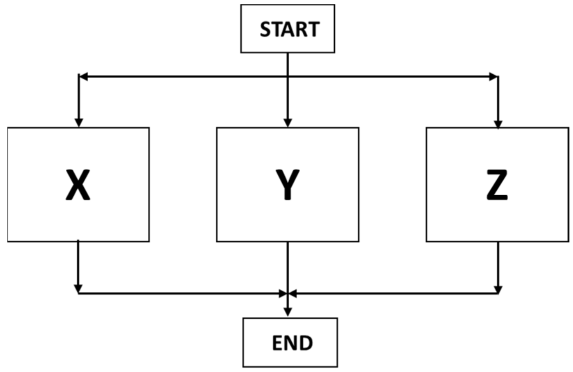
$$R_{SUT} = 1 - (1 - 0.80) * (1 - 0.87) * (1 - 0.60) = 0.99 \qquad \text{(Formula 2-10)}$$

<u>Case 3</u> - How to calculate SUT reliability based on the measure of subcomponent reliability, if it is necessary to have two out of three parallel subcomponents functioning for overall system operation.

R_{SUT} is the Reliability of two X, Y, or Z subcomponents functioning out of three .

$$R_{SUT} = R_X * R_Y * R_Z + (1 - R_X) * R_Y * R_Z + (1 - R_Y) * R_X * R_Z + (1 - R_Z) * R_X * R_Y$$

Figure 2-11. SUT with Subcomponents in Parallel (2 of 3 subcomponents required)



Calculate overall system reliability if subcomponent X has a reliability of 0.8, subcomponent Y has a reliability of 0.87, and subcomponent Z has a reliability of 0.6; if the SUT requires two out of three subcomponents to work, and the subcomponents are in parallel.

Solution:

R_{SUT} is the Reliability of two X, Y, or Z subcomponents functioning out of three X, Y, or Z subcomponents to function for overall system operation.

$$R_{SUT} = 0.8 * 0.87 * 0.6 + (1 - 0.8) * 0.87 * 0.6 + (1 - 0.87) * 0.8 * 0.6 + (1 - 0.6) * 0.8 * 0.87$$
$$R_{SUT} = 0.86$$

Case 4 - How to calculate SUT reliability when subcomponent reliability is not independent.

Three assumptions are made:

1. An OMF is based on any of the three critical subcomponents failing.
2. A critical subcomponent (X) fault within the SUT may be related to other subcomponent faults (Y or Z).
3. All components have same number of operating hours.

R_{SUT} is the Reliability of subcomponent X and subcomponent Y and subcomponent Z functioning for overall system operation.

$$R_{SUT} = e^{\frac{-t}{MTBOMF}} \qquad \text{(Formula 2-2)}$$

t = mission length

$$MTBOMF = \frac{Total\ \#\ of\ Operating\ Hours}{X\ OMFs + Y\ OMFs + Z\ OMFs} \qquad \text{(Formula 2-16)}$$

Calculate overall system reliability, if the SUT has a total of 400 operating hours, subcomponent X has eight OMFs, subcomponent Y has eight OMFs, and subcomponent Z has six OMFs. Assume the average mission length is 3 hours.

Solution:

$$MTBOMF = \frac{400\,Hours}{8+8+6} = 18.2 \qquad \text{(Formula 2-16)}$$

$$R_{SUT} = e^{\frac{-3}{18.18}} = 0.85$$

$$= 0.85$$

2.9 EVALUATING RELIABILITY RESULTS

Every attempt should be made to resolve Reliability in IOT&E. This requires sufficient data to do so. As discussed earlier, if during the MBTD process analysis determines that planned SOT is insufficient, the test team should seek alternate sources of data to augment the Reliability evaluation. This can be especially challenging with high Reliability requirements. If sufficient data cannot be obtained, the test team might be forced to leave Reliability unresolved, deferring it to a later phase of test, if one is planned, or driving the need for one to be added to the Test and Evaluation Master Plan (TEMP) to resolve reliability. One can infer from this the problem does not get easier as it gets pushed later and later. That is why it is critical to do all that can be done to obtain sufficient additional data, whether it comes from DT, IT, or the Fleet, to resolve Reliability during IOT&E.

When evaluating reliability results, it is important to recall what the COI question specifically asked: "Will [SUT] reliability support mission accomplishment?" To answer this, one must focus on mission accomplishment, not threshold performance. Since there are no critical tasks to address, as in the effectiveness COIs, it is easy to fall into the trap of only addressing the critical measures, and assessing them against their thresholds (when one is fortunate enough to have them). Point estimate comparison to threshold is important, and must be performed to address requirements. However, that does not provide the sole indicator of whether system reliability supports mission accomplishment.

Systems should be designed with reliability that supports mission requirements. However, this is not always the case. Too often, they are designed for Availability, without proper consideration for Reliability mission requirements. Consider the following example[20]:

> *A system's requirements (per the CDD) include $A_O \geq 0.98$ Key Performance Parameter (KPP) and MTBOMF $\geq$ 23.84 hours. Assuming failure data are exponential with a constant failure rate, what is the probability of completing a 7-hour mission without an OMF using the required rate of failure? R is calculated as follows:*

$$R = e^{\frac{-t}{MTBOMF}} \qquad \text{(Formula 2-2)}$$

[20] From the TE brief to TEV300, July 2018, given by Steve Hutchison, Director Office of T&E, Homeland Security.

$$R = e^{\frac{-7}{23.84}} = 0.75$$

This means, although system availability may be at 98 percent, there is a 75 percent chance of completing a 7-hour mission without an OMF at the required failure rate. This is the result of designing for Availability, vice reliability. It could also indicate the requirements author (resource sponsor) used a different mission duration or failed to consider it determining the requirements.

If the user desires a reliability of 90 percent (for the 7-hour mission), the MTBOMF required would be:

$$R = 0.9 = e^{\frac{-7}{MTBOMF}}$$

$$MTBOMF = \frac{-7}{\ln(0.9)} = 66.64\ hours$$

One can see the required Reliability (per the CDD) is insufficient to support mission requirements. Although both the Availability KPP and Reliability thresholds are met, the Availability and Reliability COIs may still be determined UNSAT, and the system Not Suitable.

When analyzing reliability results, consider the following:

- What was the system's demonstrated performance and how did they compare to thresholds?
- How did the system's reliability compare to legacy systems?
- What was the impact of redundancy built into the system?
- Were there any issues affecting user safety?
- For multi-mission systems, what was the measured reliability with respect to each mission area (R_{MA})?
- When computing R, consider all valid mission lengths and types and calculate R for each. This requires determining multiple values for "t."
- Were there any issues identified (i.e., deficiencies or risks)? How many and what severity? What were their mission relations?

In the end, the impacts of Reliability on Availability and execution of the mission must be discussed. This should be done directly in the Reliability section of the report. Maintainability and Logistic Supportability must also do this. The results sections for each of these COIs must address how it positively or negatively affects Availability. This is needed to understand how the three legs of the stool help to support Availability.

3.1 DISCUSSION

Maintainability, in OT&E, is the capability of an item to be retained in (preventive maintenance), or restored to (corrective maintenance) specified conditions, when maintenance is performed by personnel having specified skill levels, using prescribed procedures and resources, at the prescribed level of maintenance and repair.

Specific aspects of the Maintainability evaluation include an assessment of:

- Defined quantitative and qualitative corrective and preventive performance metrics,
- Maintainer training,
- Maintenance documentation,
- Maintenance tools and support equipment,
- Maintenance manpower,
- Onboard/on-station parts supply,
- Maintenance space requirements, and
- SUT and component accessibility.

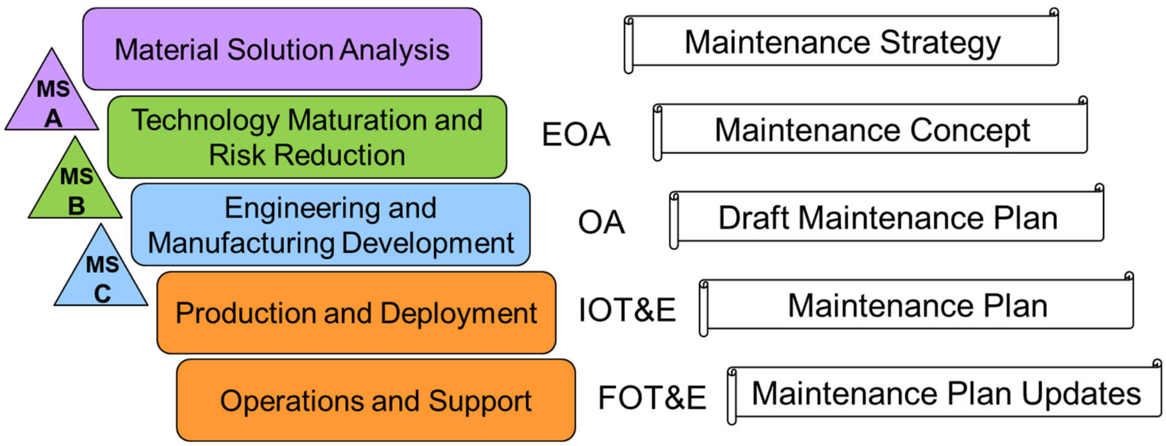
This may be achieved during the conduct of operational vignettes, or during specific maintenance action vignettes or Maintenance Demonstrations (M-DEMO).

Ultimately, the evaluation of Maintainability comes down to "When the SUT breaks, can it be easily repaired/restored? Moreover, if the SUT cannot be easily restored, why not, and what was the impact on Availability?" Reasons may be related to system design, operational environment, human factors, or any combination of the items in the bullet list above.

3.1.1 The Maintenance Plan

The Maintainability evaluation should begin with an assessment of the maintenance concept. Depending on where a program is in its development, the Maintenance Plan could be in one of a number of states of development (figure 3-1). All Maintenance Plans begin as strategies, yet should evolve with system development. This strategy should develop into a concept by Milestone B. This concept should describe broad maintenance requirements, considerations, and constraints for the SUT. It should also define the intended maintenance levels of repair, workload distribution within the maintenance system, and the force structure required to maintain the SUT.

Figure 3-1. Maintenance Plan Evolution



When conducting an EOA, there may be little else to assess than the Maintenance Concept itself. Prior to Milestone C, there should be a draft plan that may or may not be mature enough to evaluate, along with corrective maintenance time during an OA. By IOT&E, the Maintenance Plan should be in a form that fully describes how maintenance on the SUT will be conducted.

It should:

- Detail maintenance requirements and resources needed
- Prescribe actions for each significant maintenance task
- Explain technical requirements (e.g., where and how maintenance will be performed)
- Incorporate detailed support concepts and resource requirements
- List the significant consumable items
- List the supply, maintenance, and recoverability requirements / sources for each repairable item

The Maintenance Plan should not only fully describe the above items; it should be fully in place as well. All maintenance and logistic support for the SUT should be conducted per the Maintenance Plan, and therefore, be evaluated using the full range of quantitative and qualitative measures.

In the IEF Sustainment Concept section, the test team must describe the maintenance and logistics concepts. Recommended areas of discussion include:

- Corrective and preventive maintenance
- Levels of repair
    - Operational, intermediate, depot-level interactions
- General overall repair policies (e.g., "repair or replace" criteria)
- Organizational responsibilities for maintenance
- Anticipated availability of resources
- Use of contractor maintenance
- Statutory and regulatory maintenance guidance

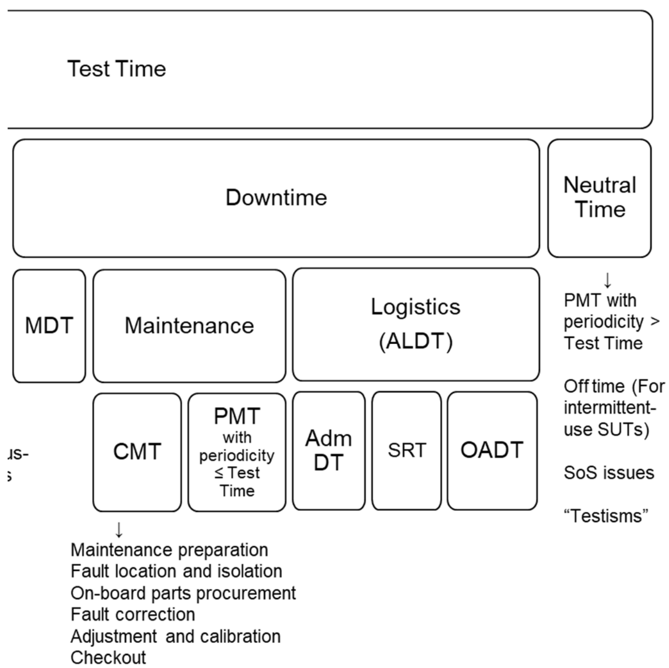
3.1.2 Organizational Levels of Maintenance

The Maintenance Concept covers the full range of Depot-level (D-level), Intermediate-level (I-level), and/or Organizational-level (O-level) maintenance. OT is primarily concerned with O-Level maintenance. However, testing other levels may be justified, particularly for a SUT with a non-standard maintenance concept. The capability of Depot and Intermediate levels of maintenance are relevant to OT, only with respect to their contributions to Availability. That is, the time it takes those organizations to perform the work required to aid in restoring the SUT is included in Off-Board LDT.

3.1.3 Contribution of Maintainability to Availability

Maintainability contribution to Availability should be the mission relation associated with Maintainability Blue Sheets. Major SUT maintenance problems impact the downtime components of Availability. These downtime components are the times to perform preventive and corrective maintenance (see figure 3-2 below). If the problem impacts the ability to perform required corrective maintenance, therefore adversely impacting Availability through increased downtime; the primary COI, affected by the deficiency (paragraph 1 (a) of the Blue Sheet), will be Maintainability. The Other Affected COI (paragraph 1 (b) of the Blue Sheet) will be Availability.

Figure 3-2. Downtime Components due to Maintainability



3.2 MEASURES

As discussed in chapter 1, failures and faults provide the connective tissue throughout the Suitability evaluation, helping to evaluate Maintainability, Logistic Supportability, and ultimately Availability. For Maintainability, understanding the time it takes to perform maintenance (i.e., CMT) is used as the primary measure. During IOT&E and FOT&E, with fully mature systems and a fully implemented Maintenance Plan, one should see the impact of repairing failures on Availability, specifically, the contribution of downtime associated with repairing OMFs.

Qualitative considerations (e.g., documentation, procedures, training, special tools, accessibility, space requirements, etc.) can also aid in understanding the key issues affecting Maintainability. That is, they can help uncover the factors that contribute to high CMTs and low availability. For this reason, tests should be designed combining both quantitative and qualitative measures. During EOAs and OA, when the Maintenance Plan may not yet be in place, one may be forced to rely on these qualitative aspects to assess risk. CMT may or may not be representative enough to aid in this assessment. Therefore, the test limitations must be examined carefully, with their impact to the Maintainability COI. In these cases, understanding these qualitative considerations becomes more important.

3.2.1 Quantitative Measures

The next few sections discuss quantitative measures and how they can be used to support an understanding of Maintainability[21]. The following discussion of measures should be used in conjunction with Appendix B of this handbook, which includes specific DRs for each measure.

3.2.1.1 Corrective Maintenance

A common thread through the test should be the OMFs (or EFFs in cases where conditional scoring of OMFs exists). These may be due to HW failures or SW faults. If measuring MTBOMF with respect to HW and SW, MCMTOMF should be measured in a similar way. Each OMF must be corrected, repaired, or restored, to evaluate Maintainability, Logistic Supportability, and Availability fully. Data should be collected to support metrics for determining the repair/restoration time associated with each OMF. Consult with the LTE/01B/01C for cases where Maintainability and/or Logistic Supportability problems preclude OMF restoration.

[21] Note, confidence intervals are not generally computed on the measures (i.e., means or medians) discussed in this chapter due to the nature of data used. They are useful as indices of Maintainability and explain the maintenance portion of downtime affecting Availability. Therefore, do not perform inferential statistics on the data; instead merely report the appropriate summary statistic for the measure.

3.2.1.1.1 Hardware Failures

The following measures are used to characterize the effort required to repair HW failures:

Mean Corrective Maintenance Time for Operational Mission Failure – Hardware ($MCMTOMF_{HW}$)
Every test design for repairable SUTs shall include, as a minimum, $MCMTOMF_{HW}$ (formula 3-1). This requirement is irrespective of whether the metric is specified in a requirements document. If MTBEFF is used, then MCMTEFF will be used as the critical quantitative measure for Maintainability.

$$MCMTOMF_{HW} = \frac{Total\ Elapsed\ Time\ to\ Correct\ HW\ OMFs}{Total\ Number\ of\ HW\ OMFs} \qquad \text{(Formula 3-1)}$$

Note: MCMTEFF should be used when conditional OMF scoring exists.

CMT includes time for maintenance preparation, fault location and isolation, fault correction, adjustment and calibration, and follow-up checkout time. It includes onboard logistic delays, which is the logistic delay associated with obtaining the spare part at the unit or O-Level. However, it does not include Off-Board Logistic Delay Time, which is captured in Logistic Supportability measures (i.e., MLDTOMF, Mean Logistic Delay Time (MLDT)). It is important to note total elapsed CMT may be different from the CMT contribution to downtime, due to possible concurrent maintenance actions to restore OMFs. This calculation assumes once the critical hardware failure is repaired (including post-maintenance inspections, equipment checkout, etc.) the system is immediately ready to resume its mission.

Since the purpose of this measure is to characterize the time it takes Fleet maintainers to perform corrective maintenance on critical subsystems, all available OT data should be used. This may result in the number of OMFs used for this measure being different than the number of OMFs used in reliability calculations. For example:

- The repair of failures scored as not OT representative for reliability (e.g., operated improperly or outside the environment for which it was designed, etc.) is still relevant for corrective maintenance measures.
- If no actual OMFs are experienced during testing, the measure must rely on failures simulated during Maintenance Demonstrations (M-DEMOs).
- At times, a SUT may contain multiple configurations with different levels of redundancy for mission critical components. In these cases, a failure may be scored as an OMF in one configuration, but as a non-critical failure in another. For Maintainability, what's important is the repair of the subsystem itself, not whether it was part of a particular configuration. All failures of the subsystem in question should be used in $MCMTOMF_{HW}$ calculations.

Mean Time to Repair Hardware ($MTTR_{HW}$)
MTTR (formula 3-2) is similar to MCMTOMF. Instead, it includes all failures (both critical and non-critical). Although MTTR may be designated in test design and planning as a non-critical measure, it should be measured during all tests. Exceptions can be made for platform-level systems (e.g., LHA, CVN, SSBN), when doing so would be impractical. There are two reasons why MTTR is required. First, high values for non-critical failure repair time can negatively affect Maintainability. Even though these failures do not rise to the level of an OMF, the aggregation of such failures can consume excessive maintenance resources. Second, for systems with built-in redundancy, a failure of a component of a

mission-critical subsystem may not result in an actual OMF. The corrective maintenance time for these failures would not be captured in MCMTOMF, but would instead only be represented in MTTR.

$$MTTR_{HW} = \frac{Total\ Elapsed\ Time\ to\ Correct\ All\ HW\ Failures}{Total\ Number\ of\ HW\ Failures} \qquad \text{(Formula 3-2)}$$

It is important to note DRs for MTTR are the same as those for MCMTOMF. The decision, whether to score a failure as an OMF, is not made during test (affecting the data being collected); it is made during the OTSB (after all data are in hand). Scoring decisions determine the sets of data that feed the calculations of MTTR or MCMTOMF. Therefore, measuring MTTR does not increase the data collection burden.

3.2.1.1.2 Software Faults

During OT, corrective maintenance associated with a SW fault only includes rebooting/restoring the system. It does not include correcting faulty SW code. The HW/SW relationship should be consistent with the relationship used for the OMFs in the Reliability COI evaluation. If $MTBOMF_{HW}$ and $MTBOMF_{SW}$ are calculated, then both $MCMTOMF_{HW}$ and $MCMTOMF_{SW}$ should be calculated. The same applies for compilation of both HW and SW.

<u>Mean Corrective Maintenance Time for Operational Mission Failure Software ($MCMTOMF_{SW}$)</u>
$MCMTOMF_{SW}$ (formula 3-3) is defined similarly to $MCMTOMF_{HW}$.

$$MCMTOMF_{SW} = \frac{Total\ Elapsed\ Time\ to\ Restore\ System\ after\ SW\ OMFs}{Total\ Number\ of\ SW\ OMFs} \qquad \text{(Formula 3-3)}$$

A description of when the system is considered to be "restored" should be included in the test plan. The assumption is SW faults are restored to the same level of readiness as when HW failures are repaired. Restoration time must include not only time to reboot the system, but also the time associated with restoring all processes, functions, files, and databases to a tactically useful state. "Tactically useful" means the operator is now ready to employ the system to support a SUT mission. For example, consider a Command and Control (C2) system that loses its Electronic Intelligence (ELINT) parameter database, whenever the system experiences a critical SW fault. To recover the information, the operator must load a separate backup tape onto the system. Assume this system experiences a SW critical fault that requires 30 seconds to reboot the system, plus an additional 1.5 hours to load the backup tape to regain the ELINT database and start processing tactical information. If the system's mission requires the ELINT database to prosecute targets, then to say the system only requires an average of 30 seconds to be restored is misleading. The system is powered and on-line after the 30-second reboot. However, it is not possible for the ship to process contacts until the backup tape is loaded. In this case, the restoration time for $MCMTOMF_{SW}$ calculation would be 1 hour, 30 minutes, and 30 seconds, as that is the time required to process useful tactical data and to inform the operator.

<u>Mean Corrective Maintenance Time for Operational Mission Failure Systems ($MCMTOMF_{SYS}$)</u>
It is contrary to accepted practice to report a single overall system maintenance value for any system. $MCMTOMF_{SYS}$ (formula 3-4) should not be reported, unless needed to answer a specified requirement.

$$MCMTOMF_{SYS} = \frac{Total\ Elapsed\ Time\ to\ Correct\ OMFs}{Total\ Number\ of\ HW\ and\ SW\ OMFs} \qquad \text{(Formula 3-4)}$$

Historically, "repair times," associated with the correction of HW failures, are significantly different from those connected with restoration of SW functions. Combining these two distinct groups of data often results in a bimodal distribution, with one-mode representing SW restoration times, and the other representing HW corrective maintenance times. The average value of such a distribution falls between the two peaks of the distribution, and does not adequately represent the "repair times" associated with either HW or SW. Therefore, for SW-intensive systems, the preference is to report a separate value, $MCMTOMF_{SW}$, involving system restoration times linked to critical SW faults.

Mean Time to Repair Software ($MTTR_{SW}$)

Similar to $MTTR_{HW}$, $MTTR_{SW}$ (formula 3-5) considers restoring all (both critical and non-critical) SW faults. The decision whether to measure MTTR should be consistent with the use of $MCMTOMF_{SW}$, and measures in the Reliability COI (e.g., $MTBOMF_{SW}$ and $MTBF_{SW}$).

$$MTTR_{SW} = \frac{Total\ Elapsed\ Time\ to\ Correct\ All\ SW\ Faults}{Total\ Number\ of\ SW\ Faults} \qquad \text{(Formula 3-5)}$$

Mean Reboot Time (MRT)

Knowing the average time required to reboot a system's SW is also useful in understanding a system's Maintainability. MRT (formula 3-6) measures the elapsed time required to reboot a SW-intensive system, following the occurrence of any SW fault, regardless of severity.

$$MRT = \frac{Total\ Elapsed\ Time\ to\ Reboot\ a\ SW\ Intensive\ System}{Total\ Number\ of\ SW\ Reboots} \qquad \text{(Formula 3-6)}$$

Unlike $MCMTOMF_{SW}$, MRT includes only the time required to reboot the system physically, and not the time required for restoring all processes, functions, files, and databases to a tactically useful state. If the system has several possible reboot configurations (e.g., cold starts or warm starts), a separate MRT value is calculated for each (e.g., MRT_C, MRT_W). While MRT is usually constrained by the technical specifications of the SUT, its impact on the capability of the platform to regain its mission capability makes it an operational concern. However, it is a secondary measure of SW maintenance and should not be used as a substitute for $MCMTOMF_{SW}$.

3.2.1.2 Preventive Maintenance

Maintainability considers not only the capability to restore an item to a specified condition, but also the capability to retain it in that same specified condition, meaning preventive maintenance must also be evaluated. This requires an understanding of preventive maintenance. Preventive maintenance can be a significant portion of downtime, depending on the system.

Mean Preventive Maintenance Time (MPMT)

MPMT (formula 3-7) should be measured when required.

$$MPMT = \frac{Total\ Elapsed\ Time\ to\ Complete\ PM}{Total\ Number\ of\ PM\ Actions} \qquad \text{(Formula 3-7)}$$

PMT is the total time required to perform the following five sub-components: (1) maintenance preparation, (2) onboard parts and consumables procurement, (3) correction, inspection, servicing, (4) adjustment and calibration, and (5) checkout/quality assurance.

While PMT's contribution to the A_O calculation is limited to those preventive maintenance actions with a periodicity shorter than the duration of the phase of test, all PMT is used to calculate this measure, as discussed in chapters 1 and 5. Even though it may not drive downtime, uptime PMT may have a significant impact on maintenance resources (specifically manpower). Since some PMT is downtime, and some is uptime or neutral time; it could be meaningful to breakout the specific contribution of PMT to downtime in Availability depending on the SUT.

3.2.1.3 Diagnostic Measures / Built In Test (BIT)

BIT sub-systems are designed to provide operators with an equipment or system status report, and provide maintainers with a fault detection and isolation tool for troubleshooting the repair of a system. When working properly, they can be valuable tools. However, problems can arise when a BIT indicates a system is not working properly, when actually it is, or when it indicates a system is working properly, when it is not. The first issue can lead users to not use the system, or mistrust the BIT sub-system in general due to excessive false alarms. The second issue can lead to failed mission tasks, or worse lead users to trust a degraded (or inoperative) system potentially placing them unnecessarily in harm's way. These issues impact Maintenance, Availability, mission effectiveness, and user safety.

All failures and faults are counted for BIT, both OMF and minor failures. When should BIT indications be counted in OT? As defined in documentation: either during SOT (for aviation: in flight), or all the time (including maintenance time). Be consistent during testing. Count every BIT record on every kneeboard card, not just when a work order is written. Some failures are not detectable by BIT, because they are not connected to the BIT system. These failures should not be included in BIT measure calculations.

BIT is addressed using the following parameters: Probability of Correct Fault Detection (P_{CFD}); Probability of Correct Fault Isolation (P_{CFI}); and Probability of a BIT False Alarm (P_{BFA}). It is recommended all three measures be used together, to ensure a complete picture of BIT performance.

Some programs use a complex system of Fault Isolate and Detect (FID) codes during DT to categorize BIT indications. If the OTD or analyst does not understand the definitions of the FID codes, or it is not known how these codes apply to these OT formulae, do not use FID codes for OT. It is not required to categorize BIT in terms of DT codes. Provide the raw data from OT, and allow the DT engineers to categorize the data for their purposes.

Probability of Correct Fault Detection (P_{CFD})

P_{CFD} (formula 3-8) is a measure of BIT's capability to detect failures/faults correctly.

$$P_{CFD} = \frac{Number\ of\ Failures/Faults\ Correctly\ Detected\ by\ BIT}{Number\ of\ Actual\ System\ Failures/Faults} \quad \text{(Formula 3-8)}$$

Probability of Correct Fault Isolation (P_{CFI})

P_{CFI} (formula 3-9) is a measure of BIT's capability to isolate the failure/fault correctly to a specified replaceable assembly.

$$P_{CFI} = \frac{Number\ of\ Failures/Faults\ Correctly\ Isolated\ by\ BIT}{Number\ of\ Failures/Faults\ Correctly\ Detected\ by\ BIT} \quad \text{(Formula 3-9)}$$

Note, the numerator P_{CFD} and the denominator of P_{CFI} are the same. For P_{CFI}, "correctly isolated" requires a determination to some level, defined in the requirements document or TEMP, as one or more components (i.e., Line Replaceable Units (LRU) or shop replaceable assemblies). All inputs for the P_{CFD} and P_{CFI} formulae are actual failures/faults, determined by maintenance actions; not BIT indications when the BIT light comes on. The numbers of BIT "attempts" and "indications" are not inputs to these formulae. A BIT indication of a real failure only is counted once until the failure is repaired and the system is tested again. Common sense says the system failed only once, not 100 times because 100 of the same indications were seen.

BIT False Alarm (BFA) Measures

A BFA indicates a failure where, upon investigation, it is found the failure cannot be confirmed. They include:

- Intermittent indications that clear, when the fault logs are reset or are reinitialized by subsequent BIT cycles (may be automatic BIT or on demand BIT),
- Indications, which do not require maintenance actions and are set because of poor SW and/or HW design,
- Indications, which cannot be confirmed by organizational maintenance personnel, when the suspected faulty LRU is found to perform satisfactorily at higher levels of maintenance.

Therefore, BFAs are determined by maintenance actions. A BIT indication of a failure only becomes a BFA after the maintenance action determines no failure was found. All inputs to the BFA formulae are BIT indications, not actual failures or faults, the opposite of the P_{CFD} and P_{CFI} formulae. Probability of BFA (P_{BFA}) (formula 3-10) characterizes the likelihood that a BIT indication is false.

$$P_{BFA} = \frac{Number\ of\ Incorrect\ BIT\ /\ Fault\ Indication}{Total\ Number\ of\ BIT\ Failure/Fault\ Indications} \qquad \text{(Formula 3-10)}$$

The problem with the P_{BFA} formula, a simple ratio, is if only a few BIT indications are encountered during test, and many are BFAs, the probability of these can be very high. If given a choice, recommend using formula 3-11 instead of formula 3-10. Consider the extreme example of only two BIT indications during test, one of which is a BFA; the probability of BFA would be 50 percent. Therefore, the number of false BIT indications, per system operating hour (BIT False Alarms per hour (BFAh) (formula 3-11)) or Mean Time Between BIT False Alarms (MTBBFA) (formula 3-12), are often more meaningful measures of BFAs; which operators can understand easily. MTBBFA is the inverse of BFAh.

$$BFAh = \frac{Number\ of\ Incorrect\ BIT\ /\ Fault\ Indication}{Total\ Number\ of\ Operating\ Hours} \qquad \text{(Formula 3-11)}$$

$$MTBBFA = \frac{Total\ System\ Operating\ Time}{Number\ of\ Incorrect\ BIT\ /\ Fault\ Indication} \qquad \text{(Formula 3-12)}$$

Note: BFAh data will likely behave in a Poisson distribution. MTBBFA should behave similar to MTBOMF data. If so, a two-sided confidence interval can be computed, although not required[22].

[22] See exact method in: http://www.nwph.net/Method_Docs/User%20Guide.pdf.

3.2.1.3.1 Other Quantitative Measures

Maximum Corrective Maintenance Time for Operational Mission Failures (MaxCMTOMF)
MaxCMTOMF is the time below which a specified percentage of corrective maintenance tasks must be completed to restore the system to operation after an OMF. This parameter is recommended, when the time required to repair and restore the system, due to operational urgency, is considered an important aspect of the SUT. In a combat situation, for example, the Commanding Officer often needs a worst-case estimate of how long he can expect a failed system to be down. This type of information is not available from MCMTOMF. What is desired, is a time-to-repair parameter that measures the maximum time required to accomplish a large majority of the repair actions. Note, in measuring MaxCMTOMF, the percentile is held constant. MaxCMT may also be used; it is similar to MaxCMTOMF, but includes all corrective maintenance, not just actions required to correct OMFs.

From a statistical perspective, this percentile should not be established at the 100 percent mark; i.e., the measure should not focus on the maximum time observed in testing. The sample size required to establish the "maximum" repair time with any reasonable confidence would be enormous. The 95th percentile is often used, but it, too, requires a significantly larger sample size to validate confidently. The 90th percentile is the most commonly used.

Maintenance Ratio (MR)
MR[23] (formula 3-13) is a measure of the ratio of total maintenance man-hours required to perform required preventive maintenance and repair all hardware failures to operating/flight hours.

$$MR = \frac{\substack{Total\ Maintenance\ Man\text{−}Hours\ to\ Accomplish\ Required \\ Preventative\ Maintenance\ and\ Repair\ all\ Failures}}{Total\ System\ Operating/Flight\ Hours} \qquad \text{(Formula 3-13)}$$

3.3 EXAMPLE

For the following example, the SUT is a continuously-operated software-intensive system.

Formulae 3-1, 3-3, and 3-4 are used to characterize overall system Maintainability. Note, $MCMTOMF_{SYS}$ is measured only when it is a specified requirement.

$$MCMTOMF_{HW} = \frac{Total\ Elapsed\ Time\ to\ Correct\ HW\ OMFs}{Total\ Number\ of\ HW\ OMFs} \qquad \text{(Formula 3-1)}$$

$$MCMTOMF_{SW} = \frac{Total\ Elapsed\ Time\ to\ Restore\ SW\ OMFs}{Total\ Number\ of\ SW\ OMFs} \qquad \text{(Formula 3-3)}$$

$$MCMTOMF_{SYS} = \frac{Total\ Elapsed\ Time\ to\ Correct\ OMFs}{Total\ Number\ of\ HW\ and\ SW\ OMFs} \qquad \text{(Formula 3-4)}$$

Given the data set in table 3-1, calculate each of the three measures described above.

[23] Memorandum of Agreement on Multi-service Operational Test and Evaluation (MOT&E) and Operational Suitability Terminology and Definition, September 2020.

Table 3-1. Sample CMT Supporting Data MCMTOMF (HW/SW) Supporting Data (SAMPLE)			
When Occurred (Date, Time)	**OMF Type (HW/SW)**	**HW CMT (min)**	**SW CMT (min)**
1/13/2019 15:50	SW		60
1/16/2019 9:00	HW	36	
1/18/2019 11:46	HW	150	
1/24/2019 9:00	SW		80
1/25/2019 9:00	HW	30	
1/26/2019 12:15	SW		45
2/2/2019 7:29	SW		117
2/3/2019 8:36	HW	24	
2/4/2019 23:29	SW		7
2/5/2019 0:46	SW		1
2/5/2019 20:37	SW		6
2/9/2019 0:32	HW	50	
2/9/2019 23:21	HW	150	
2/12/2019 18:24	SW		4
2/13/2019 9:08	SW		11
2/15/2019 20:08	SW		5
2/16/2019 10:12	HW	10	
2/16/2019 12:58	SW		20
2/17/2019 22:37	HW	12	
2/18/2019 23:53	SW		11
2/19/2019 0:39	SW		5
2/19/2019 8:03	SW		20
2/19/2019 9:35	SW		73
2/20/2019 6:06	HW	10	
2/21/2019 15:04	HW	20	
2/21/2019 22:58	SW		18
2/22/2019 1:51	SW		10
2/24/2019 2:11	HW	150	
2/25/2019 1:31	SW		20
2/25/2019 19:08	HW	24	
2/27/2019 6:09	HW	50	
		716	**513**

Solution:

Calculations for $MCMTOMF_{HW}$, $MCMTOMF_{SW}$, and $MCMTOMF_{SYS}$ are presented below:

$$MCMTOMF_{HW} = \frac{716\ min}{13\ OMFs} = 55.1 \text{ min} = 0.92\ hours \qquad \text{(Formula 3-1)}$$

$$MCMTOMF_{SW} = \frac{513\ min}{18\ OMFs} = 28.5 \text{ min} = 0.48\ hours \qquad \text{(Formula 3-3)}$$

$$MCMTOMF_{SYS} = \frac{1229\ min}{31\ OMFs} = 39.6 \text{ min} = 0.66\ hours \qquad \text{(Formula 3-4)}$$

However, first perform some EDA to verify distribution of CMT data. In planning to use a *mean* as a descriptive statistic of the data set, one assumes (whether conscious of it or not) the mean will best represent the central tendency of the data. Is this true? Figures 3-3, 3-4, and 3-5 display distributions of the HW, SW, and the combined data, respectively.

Figure 3-3. Distribution of HW CMT Data

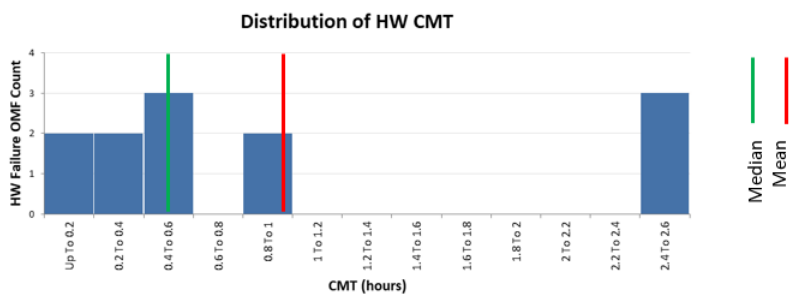


Figure 3-4. Distribution of SW CMT Data

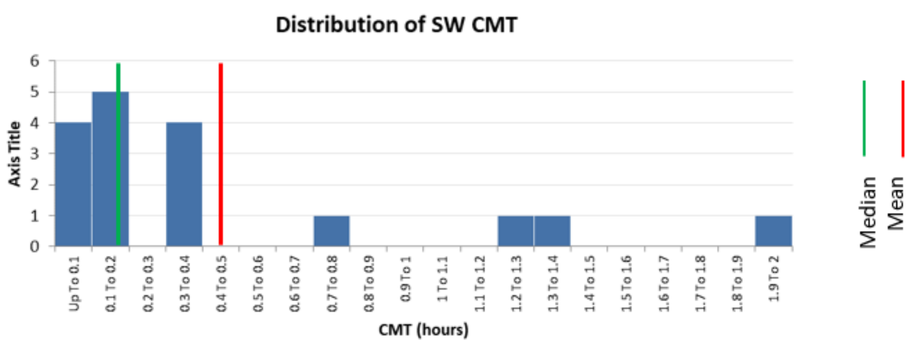
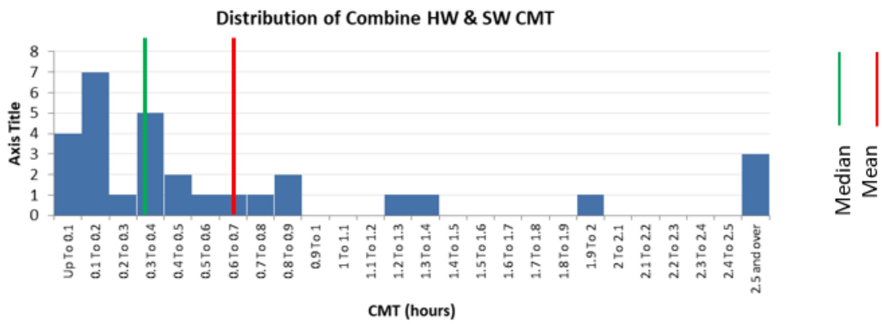


Figure 3-5. Distribution of HW/SW Combined CMT Data



For the HW, SW, and system level data, as depicted in figures 3-3, 3-4, and 3-5, a *median*, would better describe the most likely value. See table 3-2 below. Corrective maintenance times often have skewed distributions, as there are usually few long repair times and many short repair times.

Table 3-2. Mean versus Median Results CMT Results (hrs)			
	Total	**Mean**	**Median**
CMT HW	11.60	0.92	0.50
CMT SW	8.60	0.44	0.18
CMT SYS	20.50	0.65	0.33

For cases like this, where the planned analysis does not best describe the data, it is recommended to report each of these results in the data analysis summary. However, if specific results are discussed in the report, only discuss those that are most meaningful.

3.4 QUALITATIVE CONSIDERATIONS

The provision of documentation, support equipment and special tools, and manpower are evaluated as part of the Logistic Supportability COI. However, those aspects, specific to maintenance, should be evaluated as part of the Maintainability COI. These aspects are discussed below, along with training as it relates to Maintainability. Assessments of each should be captured via distinct measures. As discussed earlier, these measures can aid in understanding the key factors affecting CMT. Therefore, they should be used in conjunction with quantitative measures.

The maintenance concept should be documented and reviewed. Compliance with the concept should be assessed. Roles and responsibilities should be explained. The training associated with various roles may be different, and the differences should be considered in the evaluation.

3.4.1 Maintenance Training

For SUTs, when uniformed personnel perform maintenance, the Maintainability COI evaluation must include an assessment of the training provided by the PM. If maintenance will be provided via contract support (e.g., Contractor Logistics Support (CLS), Field Service Representative (FSR), etc.), the PM would normally not provide training, and it would not be assessed. However, if there are indications where FSR/CLS training may be inadequate, annotate the issues on the appropriate data sheet. For example, if the maintenance of the SUT is FSR/CLS, those personnel may be newly hired by the vendor to support the system. Training for those new personnel may not be adequate, and may manifest itself in long downtime due to Maintainability.

Ascertain whether formal training exists or whether an interim solution is being provided. In either case, the adequacy of what is being provided must be assessed. The training curriculum should be reviewed for accuracy and completeness. Test team members should audit any classroom courses provided. For lengthy courses, the intent is not to require attendance for the duration of the course, but to spend enough time with the instructors and course materials to gain a clear understanding of how and what is taught in order to connect observed maintenance to the provided training.

3.4.2 Maintenance Documentation

Maintenance procedures should be adequate; for upgrades to an existing system, the procedures should be updated for the newer version and nomenclature. Examples of maintenance documentation are Maintenance Requirement Cards (MRC) and Interactive Electronic Technical Manuals (IETM). Review the documentation. Consider interviewing operators as to usability. Incorporation of documentation into training can be audited. Proper assignment of maintenance levels can be addressed. Content missing from documentation should be identified. Repair impacts/delays caused by documentation can be quantified.

3.4.3 Support Equipment and Special Tools

PM-provided support equipment and special tools must be adequate to perform required corrective or preventive maintenance. Inventory this equipment. Consider interviewing operators as to usability. Training on tool/equipment use can be audited. Necessary tools that are not normally provided should be identified. Repair impacts/delays caused by these items can be quantified.

3.4.4 Maintenance Manpower

Maintenance manpower must be adequate for O-level repair and PMS. If the SUT's specified number of maintenance personnel will not be available for test, this should be discussed as a limitation to test in the test plan. Consider surveying operators as to workload. Necessary missing rates should be identified. Repair impacts/delays caused by manning can be quantified. Impacts to performance of other duties by repair burden should be detailed.

3.4.5 Accessibility and Space Requirements

It is important to assess the space allotted for performing maintenance on the SUT, which should be evaluated while personnel conduct maintenance activities in operationally representative maintenance spaces. This can be difficult in many cases, especially at test squadrons where it is not possible to replicate a shipboard environment, in which case a limitation to test should be documented. Understanding SUT component accessibility is also important. Note any issues observed with accessing specific components while performing preventive and corrective maintenance. Related delays can be quantified.

3.5 MAINTENANCE DEMONSTRATIONS (M-DEMO)

When OT periods are short, or systems are highly reliable during OT, the OTD faces a situation where not enough corrective maintenance data were collected, where the adequacy of maintenance training, tools, and documentation has not be thoroughly assessed, and where an overall evaluation of the Maintainability COI falls short of what is expected. In this situation, the OTD should schedule an M-DEMO. An M-

DEMO consists of a series of Corrective Maintenance Events (CME) and can consist of an evaluation of Preventive Maintenance checks if required. The construction of each CME entails either inserting pre-faulted components in the equipment and observing fault isolation and repair, or simulating failures in less invasive ways (e.g., via white card scenarios). The goal is to see the Fleet maintainer react to an imposed failure or fault in a realistic way, and then proceed through troubleshooting, drawing of tools and parts, and completing system repair, while being timed by the Operational Test Team. Because pre-faulted modules must be constructed at program expense, often by a contractor, the requirement for pre-faulted modules must be identified early in the TEMP development process (ensuring it is captured in the test resources section), and included in the Operational Test Readiness Review (OTRR) checklist. An M-DEMO does not provide the realism of an actual system casualty repair, so data obtained from an M-DEMO will not be of the quality of an actual repair when determining MCMTOMF or MTTR.

3.5.1 When to Conduct an M-DEMO

As mentioned in chapter 2, sometimes the OT time is not sufficient to statistically resolve the Reliability COI. This limitation can also impact resolution of the Maintainability COI, since testing a highly reliable system in a relatively short test period will inevitably result in few, if any, failures. An M-DEMO period shall be included for all IOT&Es, Follow-on Operational Test and Evaluations (FOT&E) with new HW/SW components, and any other OT phases supporting a Fleet introduction decision. This ensures minimally adequate Maintainability data are available to evaluate the SUT.

3.5.2 Limitations to M-DEMOs

While MCMTOMF values derived from M-DEMOs may serve as qualitative indicators of potential maintenance performance, M-DEMO quantitative corrective maintenance time should not be combined with actual maintenance data, nor should the M-DEMO MCMTOMF result be compared to threshold values. MCMTOMF results are strongly dependent upon the selection of the particular failures examined during the M-DEMO. If this selection is not representative of the type, frequency, and distribution of the "true" population of system failures, then the results become meaningless and possibly misleading. For example, assume the pre-faulted modules selected for a system's M-DEMO are grouped in a single subsystem, which requires only minimal troubleshooting and limited "remove and replace" maintenance actions. The resultant MCMTOMF value may be uncharacteristically low, if the other subsystems require extensive troubleshooting procedures, due to poor parts accessibility or inadequate special tools. If the only MCMTOMF results are derived from an M-DEMO, and the command desires to use that information in a report, then that information should be reported with the note that states it was derived from an M-DEMO, and actual Fleet results will likely differ.

Given these limitations, of what use is an M-DEMO? The M-DEMO's true value lies in the insights it offers concerning potential maintenance problems. The following issues can be examined during an M-DEMO:

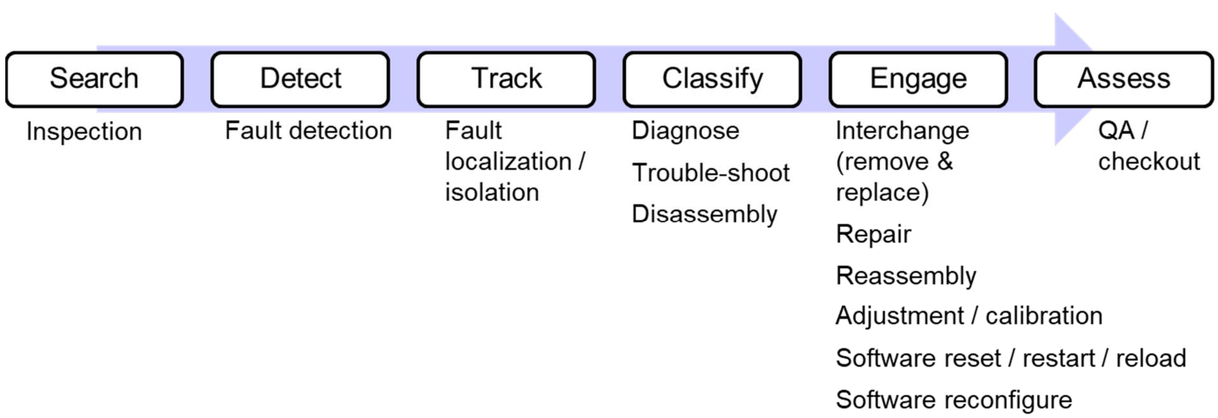
- Adequacy of BIT indications to detect and isolate the system failures induced.
- Accuracy and sufficiency of maintenance documentation.
- Adequacy of maintenance training.
- Adequacy of system design and its location on the platform in permitting timely access to failed parts.
- Documented maintenance procedures do not interfere with the continued operation of the system for those systems which permit some on-line repairs.

- Other potential anomalies in the repair of critical failures not otherwise revealed or anticipated, if an M-DEMO were not performed.

3.5.3 Planning

Plan the M-DEMO period to ensure maintenance is observed on all mission-critical subsystems. This primarily occurs during test planning. However, if certain resources are needed to support the M-DEMO(s), they need to be accounted for in the TEMP. This requires consideration during the IEF development process. It may not be necessary to conduct an M-DEMO on all of them, as some may experience failures during testing; thus providing the opportunity for maintenance to be observed. The full range of maintenance actions should also be observed during test. These include inspection, fault detection, fault localization/isolation, diagnosis/troubleshooting/disassembly, repair/re-assembly, adjustment/calibration, and Quality Assurance (QA)/checkout. These actions are analogous to a maintenance "Kill Chain," whose steps must be observed and assessed (see figure 3-6). This "Kill Chain" is not a formal representation of the maintenance process; it is merely a tool, used in this handbook, to emphasize the importance of observing relevant "tasks" and "sub-tasks," which occur, while restoring a system to an operable state.

Figure 3-6. Maintenance Kill Chain



This planning effort should result in a list of maintenance actions, which the test team must observe. When actual maintenance actions occur during test (due to observed failures); these actions can be marked off the list, leaving the remaining actions to be simulated during the M-DEMO period. For this reason, consider performing M-DEMOs near the end of the OT&E test phase. There are advantages offered by waiting until late in the test to perform the M-DEMO:

- It minimizes the risks associated with introducing faults into the SUT.
- It allows timing of maintenance actions, which were not captured during execution of the effectiveness vignettes. These actions could be important to resolving the Maintainability COI.
- It allows replication of actions, not properly entered into the appropriate maintenance action documentation system (Naval Aviation Logistics Command Management Information Systems (NALCOMIS), Defense Readiness Reporting System-Navy (DRRS-N), PMS, etc.).
- The M-DEMO may be cancelled if all the necessary data is already collected.

The failures and faults, examined in an M-DEMO, should be distributed throughout the system per their expected failure rates. They should not all be taken from high failure rate items only. Good engineering principles dictate these high failure rate items should be designed to be readily accessible to maintenance as a direct result of their high failure rates. Thus, an M-DEMO, consisting primarily of such items, may result in unrealistically low MCMTOMF values. On the other hand, an overabundance of low likelihood failures in an M-DEMO may result in the system appearing more difficult to repair than it actually is. It is important to spread the CMEs throughout the potential failures in terms of severity as well. Do not just focus on the "easy" fix items, such as filter replacement. Several failures, which would be more difficult to diagnose, should be included.

3.5.4 M-DEMO Considerations

In structuring an M-DEMO, keep the following in mind:

<u>Standardized Demonstrations</u>
Some system developers manufacture pre-faulted modules. These modules often are incorporated for use in factory training schools. Their "failures" may have a tendency to be "standardized," eliminating the element of uncertainty that would normally accompany random, unanticipated critical failures. BIT indications for these problems may also be specifically "groomed" by the developer in advance of the M-DEMO. In selecting failures, the OTD must be aware of these concerns and attempt to select failures, which are representative, as well as being somewhat unrehearsed.

<u>Golden Test Teams</u>
Hand-in-hand with the above concern is the issue of conducting an M-DEMO with maintenance personnel who have been through a more intensive training syllabus than the average Fleet Sailor would have received, or contractor personnel, who participated in the development of the system. Using such "golden" personnel skews the Maintainability results observed in the M-DEMO to artificially shorter repair times. The OTD should make every effort to use only Fleet personnel who have received the specified Navy Training Plan sequence to conduct the M-DEMO. If possible, the selection should also be across rates and skill levels to obtain a typical mix of Fleet maintenance performance.

<u>Onboard Logistics</u>
MCMTOMF, as defined by OPTEVFOR and calculated in the Fleet, includes Onboard LDT. For M-DEMO repair time data to be a useful OT indicator, operationally representative times for onboard logistics delays must be included. During the M-DEMO, tools and replacement parts should be kept in locations which realistically represent where they would actually be stored during an operational deployment.

<u>Representative Work Spaces</u>
An M-DEMO ideally should be conducted in the spaces in which the SUT will be located when deployed in the Fleet. If the M-DEMO cannot be conducted onboard the designated platform or at the identified Fleet facility, it should be conducted at a land-based test site that provides identical equipment spacing. Restricted access to panels onboard the Fleet platform should be duplicated at the land-based test site. This will ensure M-DEMO repair time data accurately reflects maintenance access times.

3.5.5 Conducting the OT M-DEMO

The following general procedures are recommended for conducting an M-DEMO (Stevens 1979):

- The maintenance team participating in the M-DEMO is removed from the test area.
- The SUT is initialized, verifying it is operating properly.
- The OTD randomly selects a pre-faulted module from the fault bank, or picks a casualty reporting method appropriate for the CME, for example having a pilot report a blank Multi-Function Display to maintenance control.
- The selected fault is inserted into the system, noting any required reconfiguration of the system, all visual "symptoms" of the fault, and any diagnostic indications.
- The maintenance team then is recalled and provided any printouts, and a verbal report of all indications of the failure. Then, the clock is started.
- The maintenance team troubleshoots and repairs the system. During this evolution, the OTD should ensure the maintenance team receives no outside inputs with respect to their troubleshooting efforts. All requests by the maintenance team for parts or special tools should be granted so as not to provide any unrealistic clues as to whether their diagnosis is correct.
- After repairing the system, the maintenance team must verify repair by performing suitable post-maintenance tests to ensure the system is functioning properly. At the completion of these tests, the clock is stopped and the repair time, associated with the particular failure, correction is recorded.

It is not uncommon during M-DEMOs for some systems to insert a failure from the fault bank, which the maintenance team cannot correct. This may result either from immaturity of the system BIT capability, from inadequate maintenance documentation, or from inadequate maintenance training. If such a circumstance arises, and the OTD decides to terminate the particular failure correction, rather than continue ad infinitum, the terminated time should not be considered reflective of the required repair time. In other words, if the OTD halts the correction of a failure after three hours, the repair time associated with the failure should not be considered as three hours, but as indefinite. Any specific reasons for the inability to correct the failure should be detailed in the evaluation report, under the appropriate COI (i.e., Maintainability, Logistic Supportability, or both).

3.5.6 Treatment of M-DEMO Data

To be clear, quantitative data can be collected, measured, and reported for M-DEMOs. As discussed earlier, for some cases these data may be all one has to support the Maintainability evaluation. However, since they introduce test artificialities, these data should be segregated from actual maintenance data observed during execution of effectiveness events. For these situations, ensure both are annotated clearly in the data analysis summary, especially when both sets are used for single measures. Although they may both be used to answer a single measure, the two sets shall not be pooled together in any one single calculation. Calculations should be made and displayed separately. Only actual maintenance data should be used to assess thresholds.

3.5.7 Example

The following is an example of an M-DEMO, and how it might appear in a test plan. Note, Section A.3.1 can be included as a stand-alone test card.

A.1.1 Test Period 1, IT-C1.1

A.1.1.1 Ground Event #1, IT 4-1, Maintenance Demos
This event will involve one or more maintenance demonstrations conducted at several points, during both test periods (IT-C1.1 and IT-C1.2) to demonstrate Maintainability aspects of specific, less frequently encountered aircraft failure modes and associated maintenance efforts on both EDM and SDTA aircraft.

A.3.1 Test Period 1, IT-C1.1

A.3.1.1 Ground Event #1: IT 4-1: M-DEMO/Eval, Maintenance Demonstration

A.3.1.1.1 DMOT
The focus of IT 4-1 Maintenance Demonstration/Evaluation is [SUT] aircraft Maintainability. The event encompasses IT-C1.1 and IT-C1.2 and collects data related to specific maintenance actions. A prioritized list of desired M-DEMOs has been formulated to be conducted, if the maintenance action has not already occurred during the course of normal flight/test operations prior to the end of IT-C1. A prioritized M-DEMO list categorized by work-center is included below:

- Flight Line
  - Air conditioning system component Remove and Replace (R&R) (including check/servicing)
  - Swashplate R&R (including quick-rig post-installation)
  - Engine R&R
  - Auxiliary Power Unit (APU) R&R
  - Tail gearbox R&R
- Airframes
  - Main rotor servo R&R
  - Tail rotor servo R&R
  - Stability Augmentation System (SAS) manifold or SAS servo (as a backup)
  - Hydraulic supply module
  - Rotor brake disc
- Avionics
  - High Frequency antenna R&R
  - Slip-ring R&R
  - APU generator R&R
  - #1 Communications Interface Unit R&R
  - Cyclic grip R&R

The event begins after all live testing in IT-C1 has been completed, and concludes when all remaining M-DEMOs have been completed. Fleet maintenance personnel will conduct demonstrations performed during this period. Test team personnel will use Ground Event Test Card #1 and complete Data Sheets #1 and #2 for every observed M-DEMO. When the last M-DEMO during IT-C1 is complete, Ground Event #1 is complete. Table A-4 summarizes Ground Event #1.

SAMPLE M-DEMO Description in Test Plan

Table A-4. Ground Event #1					
No Go Criteria	**Start of Event**	**End of Event**	**Controlled Condition**	**Associated Measures**	**Task Titles**
N/A	Completion of last live test event	End of IT-C1	N/A	M132, **M133**, M134, M153, M154, M156	N/A

A.3.1.1.1.2 Data Collection Procedures
Test team members, responsible for collecting a specific data record, are outlined in table A-5 for Ground Event #1.

Table A-5. Ground Event #1 Data Recording Responsibilities	
Responsible	**Data Record**
[squadron] Maintainer	Ground Event #1 Test Card
[squadron] Maintainer	Data Sheets #1 & #2
[squadron] Analyst or Test Info Manager	NALCOMIS

The [squadron] member designated to observe each maintenance demonstration uses the Ground Event #1 Test Card and completes Data Sheets #1 and #2 during the demonstration with input from other maintenance personnel, who participated in the maintenance action. Data sheets are submitted to the OT Analyst. The OT Analyst or test information manager downloads applicable data from NALCOMIS to satisfy data requirements. The OT Analyst then enters/logs appropriate data into the [squadron] test database.

A.3.1.1.1.3 Test Support Equipment Requirements
- Video camera (1)
- Digital camera (1)
- Stopwatch (1)

A.3.1.1.1.4 Other Requirements
- Requisite Ground Support Equipment and applicable tools for maintenance demonstration being conducted.

3.6 TEST LIMITATIONS

As discussed in chapter 1, the occurrence of failures during effectiveness testing (and preventive maintenance actions) provides the necessary opportunities to observe and evaluate the maintenance on the SUT. Without these opportunities, one is forced to rely on a well-planned and well-executed set of M-DEMOs. Therefore, even under the most operationally realistic conditions, the data could be limited, especially for highly reliable systems.

Many other factors could also stand in the way of a full and complete Maintainability evaluation, leading to limitations to test. These include:

- The Maintenance Plan is not fully in place. Possible variations include:
    - Fleet personnel are not permitted yet to perform maintenance on the SUT. In some cases, contractors still perform most (or all) maintenance tasks. However, if this is consistent with the Maintenance Plan, then, this is not a limitation.
    - Depot, Intermediate, and O-Levels of maintenance have not assumed the required responsibilities.
- Were all necessary maintenance actions observed? If not, did the M-DEMO(s) enable a sufficient Maintainability evaluation?
- Required manning was not available for test.
    - It should be understood what the source of the manning shortfall is. OT does not evaluate the Bureau of Naval Personnel's capability to provide manning, however, shortages of qualified maintainers due to deficiencies associated with SUT training are relevant.
- The location of, or conditions associated with testing allow for greater access to maintenance support facilities than in the operational (i.e., shipboard or expeditionary) environment.
- Support equipment or special tools were not available or Fleet representative.

As with all identified limitations to test, each must be described fully along with identifying the issue's impact on evaluating Maintainability and the plan for mitigation.

3.7 EVALUATING MAINTAINABILITY RESULTS

Recall from chapter 1 the fundamental question that must be answered in the test report: "Will the [SUT] be maintainable by Fleet personnel?" Similar to the discussion in the previous chapter on Reliability, the answer to this question is not based solely on threshold assessments. Will Fleet users be able to easily maintain the system, when deployed in the intended operational environment? Does it support the required Availability of the system? These are fundamental questions, which must be answered.

Quantitative results are important as they provide useful information about how long (on average) maintenance actions take, or give an indicator of how useful the BIT subsystem is in diagnosing failures and faults. When thresholds exist, those assessments are informative, especially to system designers and fleet maintainers. However, they do not provide an indicator of whether Maintainability supports system Availability. Many things should be considered. They include (at a minimum):

- What were the overall contributions of CMT and PMT to downtime?
- What were the sources of the Maintainability problems? Were any specific issues identified?
    - Were any HW failures particularly difficult to repair?
    - Did restoring any SW faults take so long as to impact Availability?

    - Were there problems with special tools, support equipment, or SUT access?
    - Were checklists and documentation incomplete or inaccurate? Did they detract from the conduct of maintenance?
    - Did required training assist personnel in performing maintenance? Did it support the complexity of repairs?
    - Were there any human factors issues?
    - Did BIT subsystems aid in diagnosing and isolating HW failures and SW faults? Did false indicators detract from operating or maintaining the SUT?
- What was the impact of manpower? Were workload requirements managed easily?

There is no formula to determine whether Maintainability is satisfactory. In the end, it comes down to whether the Maintenance Concept, as implemented, is adequate to support the necessary Availability of the SUT. This requires discussing the factors that support, or do not support, the ease with which the SUT can be maintained; and this discussion needs to relate to Availability.

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4.1 DISCUSSION

Logistic Supportability is the ease with which system design characteristics and planned logistics resources support SUT Availability and wartime usage requirements (including test equipment, spares, repair parts, configuration management, software supportability, technical data, support facilities, training, and manpower)[24]. When a system is delivered to the Fleet, the logistics for that system is part of the delivery. The fleet must execute the sustainment concept, just as they execute mission CONOPS.

Not all systems have spare parts, but all systems must be supported. Therefore, IOT&E will always include a Logistic Supportability COI. By finding problems and/or inefficiencies in sustainment, test enables greater availability, reduced Total Ownership Cost (TOC), and more. Logistic Supportability must be assessed against quantitative and qualitative measures, associated with:

- The plan for sustaining system operation and maintenance,
- The delivered and/or existing infrastructure that will implement the sustainment plan (e.g., I/D-level repair, help desk support, special shipping requirements and materials),
- The wholesale spares held by the assigned Weapon Support System (WSS),
- The retail spares on-hand at the SUT location or held by other supply system customers,
- The capability to manage, store, and replenish other system consumables (e.g. ammo, fuel),
- The provision of non-consumable items necessary to employ the system (e.g., tech manuals),
- The demands placed on the above concepts by the system's characteristics and OPTEMPO.

4.1.1 T&E Collaboration

Logistics evaluation is a multi-disciplined process. OPTEVFOR is not manned to fully accomplish this alone. As with mission effectiveness, we must collaborate with the Fleet and the acquisition community to gain the required data, analyze that information, and report the most useful findings. Several sustainment stakeholders are described below. A continual feedback loop between all of them will serve the interests of each.

4.1.1.1 Navy Supply Systems Command (NAVSUP)

NAVSUP is part of the Fleet. More specifically, they are the Fleet user of the supply system established for the system by the program, while the operators are considered the customer of the supply system. Support for aviation programs is run out of Philadelphia, PA and support for maritime programs is run out of Mechanicsburg, PA. NAVSUP integrates the end-to-end supply chain, and develops and approves the policies by which that system is run. This work includes near-term responses to fleet need, as well as forecasting of that need to maximize readiness and minimize TOC. To this end, they continually gather data and use it to adjust different aspects of the supply chain. Modeling is used as a tool in this effort. OPTEVFOR and NAVSUP have signed a MOA, creating a partnership to improve T&E of Logistic Supportability as well as real-world sustainment outcomes. By teaming up, each of the command's strengths can support the other in our specific goals related to logistics: leveraging NAVSUP's expertise

[24] OPNAVINST 3000.12A, Operational Availability of Equipment and Weapons Systems, 2 September 2003.

in logistics can help OPTEVFOR improve our evaluations with increased fidelity in measures and data requirements and in turn, OPTEVFOR's evaluations will support NAVSUP with better information to evaluate system's readiness for MSD and more.

Reliability, Maintainability, and Logistic Supportability results impact NAVSUP's mission. The measures and data for logistics must inform NAVSUP as to system performance, and sustainment risk. Sustainment responsibility for the system falls within a WSS. The specific POC will be within the Integrated Weapon Support Team (IWST). They should be consulted as part of any OT, helping to interpret logistics data such as the Consolidated Shipboard Allowance List (COSAL)/ Aviation Consolidated Allowance List (AVCAL) and/or Program Objective Memorandum (POM) procurement targets. OT information should be provided to NAVSUP as soon as possible to enable its use in improving the affected system's supply chain.

4.1.1.2 The Program Office

The primary individual(s) within the program office responsible for logistic support development and management is the Assistant Program Manager for Logistics (APML). Within larger programs, a single APML may employ several Program Sustainment Managers (PSM). The program office is charged with implementing an integrated supply chain team that will establish a supply chain that meets the operational readiness requirements of the weapon system. The IWST should be an important participant on the team. OPTEVFOR can benefit from awareness of the team's decisions, and can provide input to the team as appropriate. Program office responsibilities which can be leveraged by OT include, but are not limited to:

- Life Cycle Sustainment Plan (LCSP) development. The LCSP is discussed in paragraph 4.1.3.1.
- Sustainment Program Baseline (SPB) development. The SPB is the foundation of the program's performance-based approach to sustainment. It is meant to enable future readiness outcomes, and should be updated every two years. Status of this update, along with information provided in the PM's quarterly reports may be relevant to OT.
- Ensuring the Independent Logistics Assessment (ILA) is performed. The purpose of the ILA is to assess the feasibility and affordability of the program's product support strategy and system design to meet A_O and affordability thresholds and report those risks to the PM. An ILA shall be conducted prior to, and the results reported at MS B, MS C and FRP milestones for weapon system MDAPs. Per policy, NAVSEA and NAVAIR have independent organizations within the SYSCOM that perform the ILAs. Results are considered DT data, and may be useful to OT.

4.1.1.3 The System Operators, Maintainers, and Suppliers

Retail customers of the supply chain can provide useful input for improvement. Operators can provide input on which components and/or functions are critical to mission success and system availability, and on the correctness of OPTEMPO assumptions. Maintainers can confirm whether stated Planned Maintenance System (PMS) durations are correct, advise which components should be repaired and which should be replaced, inform O/I/D-level repair choices, and more. Supply personnel at the retail receipt and distribution point can speak to flaws in delivery and storage methods, identify flaws in the supply system information, and suggest changes to retail sparing items/inventories. OT should gather inputs from these personnel.

When a warfighting system is employed differently from how it was designed to be used, conclusions about mission capabilities and CONOPS may be flawed. The same is true for the supply system. For example, NAVSUP depends on demand data to make choices regarding consumable procurements, parts manufacturing rates, wholesale shelf amounts, retail shelf amounts, and whether items should be held at the system's location. This demand data can easily be made incorrect if end-users are obtaining parts and other consumables by means beyond the normal supply paths. These practices have, and will always occur. OT data can help mitigate this risk. Past data on parts sourcing can be gathered at the test site. The NAVSUP One Touch Support system allows the Fleet to order spare parts to use in repairs and/or to replenish onboard supplies. Parts visible in One Touch Support are either wholesale (on the shelves at WSS), or retail (on the shelf of another customer); the location of each part is shown. The need to move parts between retail locations (e.g., cannibalization from a non-operating unit) rather than "purchasing" from wholesale indicates the supply pipeline is not functioning properly. Spares procured by wholesale then transferred to customers are cheaper, and present less risk.

4.1.2 The Sustainment Lifecycle

Programs Offices support their systems from beginning to end, from development to disposal. Logistic supportability must be suitable for this entire time. To best aid this effort, logistics assessment will change between OT phases. Prior to IOT&E, measures and DRs assess risk to reaching the planned Material Support Date (MSD), the expected Logistics Delay Times (LDT) at/after MSD, and the associated risk to availability. At IOT&E, concerns are the status of reaching MSD, the readiness of supplies to sustain operations, the observed LDTs, and the impacts on availability. After IOT&E, the scope and status of changes to supplies and operations are evaluated for impacts on previous conclusions. Understanding these different stages of a program's lifecycle, and more specifically what is expected of a logistic supply chain during that stage, will better equip a test team to properly evaluate the logistic supportability as satisfactory or not. This section should help clarify those expectations by defining a few logistics concepts in further detail.

Because the system sustainment must be developed in parallel with the system and is affected by system design choices, early decisions in the program lifecycle can have significant implications for logistic supportability. Many of these decisions are based on assumptions such as Original Equipment Manufacturer (OEM) estimates. Others are based on forecasting OPTEMPO. These choices are validated and updated as the program lifecycle moves forward. More accurate information provided earlier can only benefit system sustainment. Despite the limitations, logistics supportability evaluation is always an important part of OT.

4.1.2.1 Material Support Date

At MSD, responsibility for system sustainment passes hands from the program office to NAVSAUP (NAVSUP accepts material supportability). The MSD is set based on negotiations between the SYSCOM and NAVSUP and once set, NAVSUP does not have the ability to delay. If a program has a MSD, four things must be in place when that date is reached:

- Repair capability (training, publications, tools, and personnel to complete O-level maintenance; procedures; and infrastructure to complete I/D-level maintenance),
- Spares (retail sparing breadth and depth, wholesale sparing breadth and depth, and spares manufacturing),
- Technical procedures and drawings (the information needed to manufacture system components),
- Parts buy-out funding (SCN/APN/OPN/WPN dollars accounted for in the Outfitting accounts; O&M,N dollars for Fleet flying/steaming hours program).

Currently, the PM declares MSD. If any of the above are not provided, the cost will be passed to the Fleet in COSAL plus-up and other costs. Not every system has a MSD. Almost every case where WSS is responsible for parts supply will have a MSD; while almost all others will not. For example, a system with parts support provided entirely through a contractor or by the SYSCOM will have no MSD. Nor will a system supplied only via consumables. In these rare cases, unique language must be developed to replace MSD, and indicate when operationally realistic logistic supply has begun.

4.1.2.2 The Stages of Sparing

Provisioning replacement parts generally happens in three stages: initial sparing, interim support, and NAVSUP sustainment. Understanding factors affecting sparing allows NAVSUP to be ready, informing risk decisions on what to buy-ahead, and where to delay purchases. Inadequate sparing at MSD (when NAVSUP gets the parts already bought) means greater cost to the Fleet.

- Initial spare parts are identified as the interim spares, Installation and Check-Out (INCO) spares, inventory augmentation, and Onboard Repair Part (OBRP) spares for the system end-items. All these spares shall be financed by the program office in the same procurement appropriation as the end-items.
  - Interim spares are held in wholesale, and at MSD should be at the planned breadth and depth.
  - INCO spares are owned by the PM, used as needed, and do not transfer to NAVSUP at MSD.
  - Inventory augmentation is supply pipeline growth to account for supplying a new system and/or meeting a greater parts consumption rate (e.g., higher than expected failure rate).
  - OBRP initial spares are held in retail and at delivery to the fleet should match the breadth and depth of parts planned to be at the system site during normal operations.
- Before MSD, interim support parts (different from interim spares) may come from a contract. This contract is let by the program office. Interim support parts can also come from leftovers from initial spares, and cannibalization from future production. However, when sustainment of fielded end-items and production of new end-items compete for supplies, production usually wins.
- NAVSUP holds all wholesale spares for fielded end-items, monitors retail sparing status, fills all parts requests submitted for provisioning from wholesale, and manages all contracts for parts production to meet these needs.

Of note, parts breadth is the number of different parts held at a supply location; parts depth is the number of each specific part held at a supply location; end-items are the SUT being procured by the program office and delivered to the Fleet.

4.1.2.3 T&E Throughout the Lifecycle

As stated above, T&E of logistics must be planned, executed, and reported appropriately for the status of the program. Understanding that status is vital. For example, the first time that a semi-accurate parts list might be available to logistics stakeholders might be post-Critical Design Review (CDR). No matter the status, one can at least report on what is observed in testing. The program's ultimate goal is successful operational sustainment for the system. Arrival at that destination is impacted by how far is left to go, and speed toward the goal. Both considerations are relevant at any test for which the supply chain is not finalized and stable.

During EOAs/OAs, the team often evaluates the interim logistics concept as described in existing draft documentation. This is particularly acceptable if the intent is to use them as long-term interim solutions. They must be identified as an interim/draft in the report. Perhaps no LDT data is gathered. But thorough assessment of the plan and the supply chain development progress should be sufficient to assess risk to achieving successful sustainment at IOT&E. Milestone B includes the Full Funding Decision, which should be informed by an understanding of TOC. T&E can enable consideration of supply impacts. There are likely no limitations to this logistics test, as the developmental nature is understood.

Logistic Support should be fully in place by IOT&E, but this is often not the case. If sustainment is not operationally representative, evaluate the logistics "as-is" using the concept and procedures in place. Any shortfalls discovered should be discussed in the test report. If the "as-is" logistics fails to support SUT Availability adequately, consideration may be given to an "UNSAT" determination. If the COI is left unresolved, an FOT&E must be scoped and included in the TEMP to ensure a full evaluation is performed.

For OT prior to the MSD, it is difficult to evaluate Logistic Supportability as "SAT" based solely on collected LDTs and sustainment plan status/quality. When this is the case in IOT&E or FOT&E, a limitation is needed as described in paragraph 4.4. The other measures identified in paragraph 4.2.2 were developed to mitigate this limitation.

It is very likely that the FOT&E supply chain will be different from that seen at IOT&E. Supply personnel in the Fleet can submit Allowance Change Requests (ACR) to change OBRP numbers. WSS may update wholesale parts breadth and/or depth based on monitoring Fleet requests. The program office may have issued Design Change Notices (DCN) that add or remove components from the Item Mission Essential Code (IMEC) list. Comparison to the IOT&E sustainment concept is necessary to determine scope of logistics testing.

4.1.3 The Sustainment Concept

Sustainment is complex and potentially costly. There must be an adequate plan. Design, manufacturing, intellectual property rights, and funding are slow to adapt. The plan must be comprehensive, correct, and clairvoyant (for lack of a better term). For the vast majority of T&E efforts, the LCSP is the primary documentation of the sustainment plan. ***The execution of O-level maintenance is a key part of the sustainment concept, but this is covered under the Maintainability COI.*** The rest of the concept falls under Logistic Supportability.

4.1.3.1 The Life Cycle Sustainment Plan (LCSP)

According to the Defense Acquisition University[25], "the LCSP documents the Program Manager and Product Support Manager's plan for formulating, implementing, and executing the sustainment strategy. The LCSP describes the approach and resources necessary to develop and integrate sustainment requirements into the system's design, development, testing, deployment, and sustainment phases." Per ASD(L&MR) Memo[26] issuing the updated LCSP outline, "the LCSP is the primary program management reference governing operations and support planning and execution from Milestone A to final disposal". Specifically, the LCSP should document the program plan in the following areas:

- The maintenance and logistic concepts,
- How sustainment is addressed as an integral part of the program's acquisition strategy, funding, and system design process,

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[25] From Acquipedia: https://www.dau.mil/acquipedia/Pages/ArticleDetails.aspx?aid=66d54252-1a7a-4c07-8988-c4f9962efac8.
[26] ASD(L&MR) Memorandum, "Life-Cycle Sustainment Plan Outline Version 2.0," January 19, 2017.

- The assigned responsibilities and management approach for achieving effective and timely acquisition, product support, and availability throughout the life-cycle including the Program Manager's role in planning for and executing sustainment,
- The plan for identifying and selecting sources of repair or support,
- The sustainment risk areas and management/mitigation plans,
- Software Configuration Control and Support Plans,
- Product support implementation status,
- Results and recommendations from DoD Component ILAs.

The LCSP evolves throughout a program's life, meeting changing needs at each of the acquisition milestones and beyond. The logistic support concept begins as a broad strategy, and evolves into a detailed plan documented in the LCSP (formerly the Integrated Logistics Support Plan (ILSP)). It evolves from a Product Support Strategy, which includes a description of the business and technical approach to design, acquire, and field the Product Support Package (PSP) to execute the sustainment strategy. The PSP is a collection of the 12 Integrated Product Support elements, and any sustainment process contracts or agreements, used to attain and sustain the maintenance and support concepts needed for materiel readiness. The PSP is translated then into the LCSP, which details the sustainment efforts required to achieve performance and sustainment outcomes, necessary to ensure required readiness. The LCSP provides a detailed execution plan for how the PSP is to be designed, acquired, and sustained. It also describes how sustainment will be applied, measured, managed, modified, and reported from system fielding through disposal. The LCSP must enable reaching MSD, and managing an efficient/responsive supply chain after MSD. Assessing the contents of the LCSP during all phases of test will give insight to the ability of the program to meet sustainment goals and expectations.

4.1.3.2 Repair or Replace; Hold or Ship

Speed of restoring a system to operation following failure is impacted by multiple choices made in the sustainment concept. These choices can be evaluated as risky or not, detrimental or not. Replacement on site at the O-level by fully trained operators with parts immediately available in retail at the system location is fastest.

This is because:	But on the other hand:
1. Repair takes more time than simple replacement	1. Replacing everything costs more than repairing items that can be fixed at the right level
2. When the part is not on-hand, maintenance is delayed by shipping time	2. Putting all system components in the Allowance Parts Lists (APL)/Allowance Equipage Lists (AEL) and storing those onboard is impossible
3. Sending I-level fly-away teams also takes time	3. Training O-level maintainers to repair everything is impractical
4. Shipping equipment carcasses to the depot and returning repaired units takes more time	4. D-level repairs are usually far too complex to accomplish outside a dedicated facility

The program must establish the maintenance and sparing concepts to accomplish restoration that supports availability under the constraints of schedule, budget, and personnel. More frequent and extensive PMS prevents failures but costs steaming/flight hours, dollars, and man hours. Forward-staging of parts reduces LDT, but requires the necessary infrastructure. Commonality of configuration across the force simplifies training for maintenance and operation, but limits flexibility for upgrades. All stakeholders to these concepts can recommend changes. T&E can inform changes before flaws impact Fleet readiness.

The plan for supplying consumables must also support availability. A fully operational system can be unavailable if it has no gas, bullets, etc. In addition, absence of parts that are considered consumables such as washers, seals, etc. can also drive a system to be unavailable. Consumables support for a single underway/flight/mission/engagement is an effectiveness concern. However, the supply chain's impact on keeping the consumables "topped-off" is a logistics concern. That includes loading, storage, and unloading. For example, lube-oil storage may be more than sufficient for mobility effectiveness, but this excess storage may still be insufficient for logistic suitability based on use and replenishment rates.

4.1.3.3 Non-consumables

Items necessary for system operation and maintenance such as technical manuals, training material, tools, trainer infrastructure, and more are relevant to the logistics assessment. The quality of those items is measured in effectiveness and/or maintainability. The presence of the items when and where they are needed is a logistics concern. These are non-consumables used at the O-level. Above that, such items are only considered in the context of whether the support infrastructure is adequate.

4.1.3.4 SUT, SOS, and Support Infrastructure

The details of logistics DRs depend greatly on the sustainment concept for the SUT. Is the SUT a subsystem of, or hosted by a platform which carries supplies for that system? Is the system sustained between missions by a forward-basing or pre-positioning concept? Does the system have dedicated support mechanisms beyond the typical supply system? The answers change the scope of any "onboard" parts inventory, and much more.

The sustainment concept must consider the full supply chain. Holding inadequate spares in retail at the system location is a SUT issue, but inadequate storage for consumables and non-consumables may be a SOS issue. The help-line may aid great outcomes, but be hard to reach. An I-level concept might not exist when it is needed. The depot might complete repairs and return components quickly, but the survival rate (the likelihood that a component entering the depot will be returned) may be very low while the carcass return rate is very high. The supply system might respond quickly to fill parts requests from wholesale, but the parts could often arriving damaged by shipping. All these concerns fall within logistic supportability, as appropriate for the specific test effort. They are also interrelated. For example, longer depot repair turnaround times may require greater sparing inventory to compensate.

4.1.3.5 The Replaced System

The SUT may have a Replaced System Sustainment Plan (RSSP) that documents how the legacy system items will be supported as the SUT items are fielded to the Fleet so that the entire force remains operationally capable during the transition. This is relevant to the sustainment concept because the sun-down of the prior systems may present risk to SUT logistic support. Spare parts inventories and production rates must support both.

4.1.4 Deliberately Non-representative Logistics at Test

The need to ensure system availability during test events in order to maximize data gathering, best use program dollars, and minimize impact on Fleet schedule can motivate use of non-representative logistics at test. Parts that are carried onboard may be held in greater supply. Parts normally obtained from wholesale may also be staged at the SUT location or in closer proximity. These are rational choices on behalf of testing risk mitigation, but prevent collecting operationally representative LDTs. Other logistics data collection may also be impacted. A limitation should be applied.

Mitigating the risk involves collecting additional data. The sourcing of each replacement part used at the test event is determined to be operationally representative, or not. A delay time penalty is imposed as appropriate. This penalty must be informed by supply chain data on Average Customer Wait Time (ACWT) for the witnessed source, and also for the expected source. ACWT utilizes maintenance data from DECKPLATE (Aviation) and OMNS-NG (Maritime) to compute the time the O-level retail customer (maintainer) has to wait for the part. It includes only Direct Turnover (DTO) requisitions. For example, a test being conducted underway may encounter a component failure that requires a tech-rep to fix. That person is onboard, and there is no sampled LDT. The same circumstance in the Fleet could involve the ship returning to homeport, the tech-rep flying to an overseas location, that person being away on a different job, etc. Any of these would create an LDT. Similar to an M-DEMO scenario, when a test artificiality is introduced like a delay time penalty, these data should be segregated from actual observed data during execution of effectiveness events.

This problem is further complicated if the eventual source has not been determined and/or the supply chain has no data for the system to enable approximating additional delay times. OT may be limited to making qualitative statements about the uncertainty. If nothing else, the Navy supply system has an average Logistics Response Time (LRT) of 40 days. Most LRT samples will be close to this number, as the vast majority of delay comes in the "last tactical mile." LRT uses MILSTRIP transactions through Defense Automatic Addressing System (DAAS) via the Logistics Metrics Analysis Reporting System (LMARS) for wholesale requisitions to compute a response time. It includes DTO and replenishments from the wholesale system to the customer level. It is not limited to O-level customers.

4.1.5 Contribution of Logistic Supportability to Availability

Similar to the discussion in chapter 3 (section 3.1.4), the impact of Logistic Supportability issues will be their effect on restoring the SUT to an operable status for continuous-use, intermittent-use, and on-demand SUTs. Logistics problems cause increased downtime on the system, negatively affecting Availability. For impulse SUTs, the issues center on whether sufficient quantities are on hand to support mission requirements, given rates of failure.

4.2 MEASURES

Similar to the discussion in chapter 3 (Maintainability), for repairable systems, failures provide the connective tissue throughout the Suitability evaluation, helping to evaluate Logistic Supportability and ultimately Availability. For Logistic Supportability, the time it takes to receive off-board support, LDT, is used as the primary measure. During IOT&E and FOT&E, with a fully mature logistic support system (i.e., a fully implemented LCSP), one should see the impact of logistic delays on Availability, specifically, the contribution of downtime awaiting off-board parts or support associated with repairing OMFs.

It may be difficult or impossible to measure a meaningful LDT before IOT&E, or before the SUT's MSD. It can also be challenging when logistics support provided at test is not operational representative. For example, logistics resources (to include parts and/or technical support) sometimes are pre-positioned to support testing or provided directly from program office personnel. This lack of realism may force one to evaluate Logistic Supportability via more qualitative means. LDT should still be measured; however, limitations must be discussed clearly in the test plan/report.

Qualitative considerations (e.g., documentation, training, special tools, support equipment, packaging, handling, shipping, and transportation, technical support, etc.) can also aid in understanding the key issues affecting restoration of the SUT. For this reason, tests should be designed using a combination of both quantitative and qualitative measures. During EOAs and OAs, one may be forced to rely on these qualitative aspects to assess risk. LDT will likely not be representative enough to aid in this assessment. In these cases, understanding these qualitative considerations becomes more important.

Logistic Supportability data, unless it is out of scope, will be collected and appropriate measures will be included in all test plans and evaluated in the post-test process regardless of whether the measures are called out in requirements documents. Logistic support measures must be tailored to the system. For instance, some acquisition efforts will not have an LCSP to evaluate, in which case, a measure should be created that focuses on documentation that does exist for the effort, and that measure becomes the basis for evaluating the sustainment plan. The next few sections discuss measures and how they can be used to support an understanding of Logistic Supportability. This discussion of measures should be used in conjunction with Appendix C of this handbook, which includes specific DRs for each measure.

4.2.1 Primary Measures

As with Reliability and Maintainability, the common thread through the test should be the OMFs (or EFF when conditional scoring is used). Each OMF must be corrected, repaired, or restored and parts provided to affect the repairs. Data should be collected to support metrics for determining the logistics delays associated with supporting repair/restoration of each OMF.

Two quantitative measures shall be used to evaluate Logistic Supportability: Mean Logistic Delay Time (MLDT), and Mean Logistic Delay Time for Operational Mission Failures (MLDTOMF). If the requirements documents include these measures, then the corresponding specified threshold will be used. One qualitative measure shall be used – LCSP adequate, funded, and implemented.

<u>MLDTOMF</u>

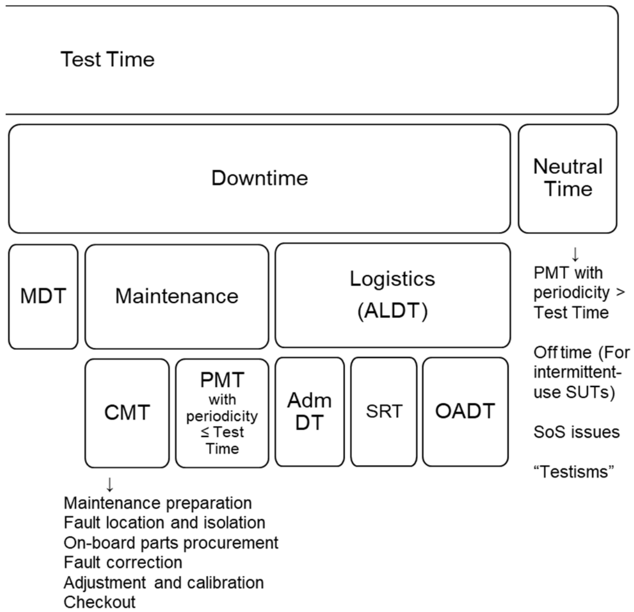
MLDTOMF (formula 4-1) is a measure of the average time a system is awaiting off-board/off-station logistics to restore an OMF. Active maintenance is not normally being performed on the downed system or subsystem. However, in some cases overlaps exist between active maintenance and logistic delay.

$$MLDTOMF = \frac{Total\ Elapsed\ Time\ SUT\ is\ Awaiting\ Offboard\ Logistics\ to\ Correct\ OMFs}{Total\ Number\ of\ OMFs\ Requiring\ Offboard\ Logistics\ Actions} \qquad \text{(Formula 4-1)}$$

Note: MLDTEFF should also be used when conditional OMF scoring exists.

Recall from chapter 1 (section 1.5) that LDT is composed of the elements depicted in figure 4-1. Examples of off-board logistics include parts request in Navy supply, pier-side supply, I-level and D-level maintenance, and contacting help desks. These requests are completed referencing stock numbers (National Stock Number (NSN) or National Item Identification Number (NIIN)), not part numbers. Anomalies in the supply chain can impact LDT (e.g., receiving a part that was not ordered); associated qualitative DRs are provided to gather these data.

Figure 4-1. LDT Components



<u>Mean Logistic Delay Time (MLDT)</u>

Logistic delays can impact mission execution even if they are not related to OMFs. It is important to understand the capability of the logistic support system to aid in restoring all failures, not just OMFs. Whereas MLDTOMF represents the average off-board/off-station logistic delay time, associated with restoring OMFs only, MLDT (formula 4-2) includes all off-board/off-station logistic delays. Both measures must be used, and MLDTOMF shall be critical. Be sure to understand whether specified requirements are associated with logistic delays for just OMFs or all failures because they likely will not use the term MLDTOMF.

$$MLDT = \frac{Total\ Elapsed\ Time\ SUT\ is\ Awaiting\ Offboard\ Logistics}{Total\ Number\ of\ Offboard\ Logistics\ Actions} \qquad \text{(Formula 4-2)}$$

<u>LCSP Adequate, Funded, and Implemented</u>

This assessment begins with determining whether/when the LCSP has been signed and funded. Although it is relatively easy to determine if the LCSP has been approved, it can be quite difficult to determine the level at which the plan has been funded, especially for systems with relatively long planned service lives. Details about implementation can be investigated to support this measure; it should be noted whether required program documentation has been provided by the PM to support use of the SUT. This includes both operating and maintenance procedures and manuals, technical manuals, and APL/AEL.

The most challenging piece to determine is adequacy of the logistics plan. In earlier phases of test (prior to MSD), the team will focus on assessing the LCSP for feasibility of concepts, progress toward goals, plans for improvement, mitigations of risk, and more. Later phases determine if the plan supports Fleet sustainment. Gathering data on the LCSP will involve significant collaboration and correspondence with the APML and/or PSM. The assessment/evaluation will have multiple considerations, including:

- Examination of how the maintenance concept directly impacts logistics. Supplies and skills must be present at each level to support the maintenance routine/workload. The split of maintenance jobs between the O-, I-, and D-levels will impact the need for parts and carcasses (broken components) to flow through the supply system. I- and D-level maintenance times fall in LDT. Thus, the adequacy of the maintenance concept to support availability is evaluated. As for the inability of a particular maintenance action to be completed at the O-level, this concern would fall under the maintainability COI. PMS is also considered for feasibility and support for availability.

- The program's Intellectual Property (IP) Strategy contains the Technical Data Plan, to include design drawings and data rights, and it must support system sustainment. These technical drawings are not the ones in tech manuals used on the ship to repair the system. Rather, they show how components are constructed, enabling future procurement of parts. The program's Chief Engineer is the expert on the technical data. Without a good strategy, parts availability may be impacted when suppliers stop production. Sole-source and no-source risk can lead to higher costs and longer delays, including the need to reverse-engineer and ramp up production on parts when stockpiles are exhausted.
- Spares in the supply system are not held exclusively for a specific SUT. Inventories are agnostic to platform and service. As a result, supply risks (costs, times, etc.) may be mitigated through building a system that uses parts common to existing systems. For example, an excess of parts procurement for ships in the fleet could save money in a new ship's sustainment (rather than those parts being purged). The design can be assessed for this purpose throughout development.
- Configuration management within the program also affects supply. SUT design stability throughout development reduces risk. Design changes (such as those resulting from reliability issues) occurring closer to IOC have higher risk of impacting MSD requirements via parts procurement already contracted and/or the parts buy-out already budgeted. Lack of a configuration management program may prevent recognizing and mitigating associated risks. SUT changes as a result of incremental upgrades have similar considerations, and require updates to configuration management.
- The RSSP is not always an important consideration for SUT suitability testing, but the OTD should be aware such a plan exists. Through conversation with the APML, determine if the RSSP will impact SUT sustainment. For example, inadequate funding of legacy system support may eventually pull resources away from the SUT.
- The program must evaluate the affordability and feasibility of the system's product support strategy using Operations and Sustainment (O&S) cost estimates. Changing operations cost may impact sustainment feasibility. However, operations costs for consumable supplies such as fuel and hydraulic oil are not part of the OT sustainment cost evaluation. As a result, they are not part of the logistic supportability COI.
- Examination of the IMEC list verifies the supply system's understanding of which parts are critical is consistent with DT and OT perspectives.

4.2.2 Other Measures

There may be other considerations, which can inform the Logistic Supportability evaluation, in addition to the ones discussed in the previous section. While MLDT and MLDTOMF can quantify the logistic delay, an assessment of the aspects described below can help in identifying the root cause of problems, and in cases of non-representative support, it may be all that is available to evaluate Logistic Supportability. Reference the measures and data requirements further documented in Appendix C for information on data sources.

<u>Percent provisioning complete</u>
This measure is relevant before, or shortly after MSD, when NAVSUP has had little opportunity to impact the parts on-hand. At MSD, numbers should be above 90%. Pre-MSD there's a glideslope, similar to the way reliability growth acknowledges that performance/status still has time to improve.

This measure is concerned with the breadth of parts, not the depth; quantities on shelves are not considered. The impact of specific parts lacking provisioning will depend on the criticality of those parts. Limited parts availability creates the risk of future increased LDTs.

The depot source of repair or source of engineering (where a part goes if it requires repair or replacement) is identified for each repairable part, and is required 90 days after CDR by SECNAVIST 5000.2G. Therefore, the In-Service Engineering Agent (ISEA) should be known before IOT&E. This identification includes consideration of Diminishing Manufacturing Sources and Material Shortages (DMSMS) risk.

$$Percent\ provisioning\ complete = \frac{Number\ of\ unique\ stock\ numbers\ assigned\ NSNs}{Total\ number\ of\ unique\ replaceable\ parts} \qquad \text{(Formula 4-3)}$$

<u>Interim support contract duration</u>
Interim support is the bridge from PM-sourced support to NAVSUP supply support. Longer contracts give NAVSUP more time to be ready to support. For most systems, the target is 24 months. Less than 18 months is cause for concern, potentially causing the Navy to assume additional unplanned lead-time risk. Impact of the duration will depend on system type/status. Understanding factors affecting sparing allows NAVSUP to be ready, informing risk decisions on what to buy-ahead, and where to delay purchases. Inadequate sparing at MSD (when NAVSUP gets the parts already bought) means greater cost to the fleet.

<u>Percent of stock numbers on-hand in wholesale</u>
At MSD, provisioned stock numbers should be on wholesale shelves. If not, the parts cannot be ordered in the supply system, leading to longer LDTs. Lack of replacement parts for order could also lead to anomalous actions in the supply system. The measure is concerned with the breadth of parts, not the depth; quantities on shelves are not considered. The status for each stock number is binary, a part is on the shelf or it isn’t. As long as a single unit is available, the supply system is ready to respond to need. The impact of specific parts lacking replacement supply will depend on the criticality of those parts.

$$Percent\ of\ stock\ numbers\ on-hand\ in\ wholesale =$$

$$\frac{Number\ of\ stock\ numbers\ expected\ in\ wholesale\ for\ which\ one\ or\ more\ single\ unit\ is\ held}{Total\ number\ of\ stock\ numbers\ expected\ to\ be\ in\ wholesale} \qquad \text{(Formula 4-4)}$$

<u>Percent of NSNs/NIINs ready for MSD</u>
IWST will consider parts use rates, parts on-hand (in both wholesale and retail), planned procurement dates, and planned procurement rates. When these data indicate a stock number’s supply will run shorter than acceptable risk margins, NAVSUP down-checks that part and it is considered not ready for MSD. With those binomial results, the measure is quantified across the breadth of parts.

The impact of this measure depends on the parts identified as unready for MSD, the severity of the numbers deficit identified (both in quantity and time), and the criticality of the part associated with the short-fall. A short-fall is only apparent if the current supply data is accurate, and the expected supply outcomes are realistic. Anomalous supply data (e.g., parts obtained from the production line, excess spares, or on the unit’s credit card, rather than from wholesale) will prevent correct evaluation by NAVSUP, and may degrade readiness for MSD. They may also result in wholesale procuring excess spares that are not required now and/or in the future, wasting capital and/or preventing capital from being available for other needs. These anomalies will not become blue sheets. The OTD should consolidate indications of anomalous supply data and send them to the IWST via email to help with the fidelity of this data.

Unlike the previous measure, this one is not limited to wholesale. The supply pipeline includes the required stockage levels for the wholesale supply management activity as well as the retail operational outfitting requirements necessary to support end-items. IWST will consider OBRP at SUTs, as well as spares at depots and intermediate maintenance facilities.

$$Percent\ of\ NSNs/NIINs\ ready\ for\ MSD = \frac{Number\ of\ NSNs/NIINs\ deemed\ ready\ for\ MSD}{Total\ number\ of\ NSNs/NIINs\ required\ at\ MSD} \quad \text{(Formula 4-5)}$$

<u>Tools and publications are on hand</u>
The LCSP measure looks at larger plans to supply the force, and has data points that can be collected away from test events. This measure is based solely on assessment of support items provided at test, versus those that were needed to sustain mission operations. Spare parts and other consumables are covered by other measures above. If those parts measures were not used, adjust this measure to look at spare parts and consumables too.

<u>Percent of out-of-stock inventory for onboard parts/supplies</u>
The onboard parts list may be sufficient, but this does not guarantee all those parts are onboard. Logistics is both the plan and the execution of supporting the system. Supply professionals track these numbers as net effectiveness (supplies of OBRPs held onboard), and gross effectiveness (all supplies held onboard). If these program-wide numbers are available, they can be compared to OPNAV 85% wholesale fill metrics. Existing supply requests can add context to the quantitative data. This measure also considers parts held onboard that should not be.

$$Percent\ of\ out-of-stock\ inventory\ for\ onboard\ parts/supplies = \frac{Number\ of\ individual\ items\ held\ in\ inventory\ onboard}{Total\ number\ of\ individual\ items\ required\ to\ be\ held\ in\ inventory\ oboard} \quad \text{(Formula 4-6)}$$

<u>Percent of hardware maintenance requiring immediate use of parts</u>
The impact of logistics on availability depends on how often logistics must support system restoration to operation. This measure covers corrective and preventive maintenance actions. It covers both onboard and off-board support. The measure accounts for the maintainability philosophy's effect on LDT, availability, and sustainment cost.

$$Percent\ of\ hardware\ maintenance\ actions\ requiring\ immediate\ use\ of\ parts = \frac{Number\ of\ hardware\ maintenance\ actions\ requiring\ immmediate\ use\ of\ parts}{Total\ number\ of\ hardware\ maintenance\ actions} \quad \text{(Formula 4-7)}$$

<u>Percent of maintenance actions requiring off-board supply and/or support</u>
The impact of off-board logistics on availability depends on how often off-board parts requests, technical support, or I/D-Level repair must support system restoration to operation. This measure quantifies allowancing efficacy by suppressing consumable/repairable parts requirements with OBRP allowance=0.

The equation A_O = MTTR / (MTTR + MCMT + MLDT) is flawed for many reasons. But with respect to MLDT, this equation assumes MLDT is calculated from all maintenance actions, not just those requiring off-board support. If the flawed A_O calculation is specified in the requirements document, MLDT calculation can be corrected using this percentage measure.

$$Percent\ of\ maintenance\ actions\ requiring\ offboard\ supply\ and/or\ support = \frac{Number\ of\ maintenance\ actions\ requiring\ offboard\ supply\ or\ support}{Total\ number\ of\ maintnenace\ actions} \quad \text{(Formula 4-8)}$$

<u>Technical support desk aids in system maintenance</u>

LDT can result from simply waiting to hear back from the help desk. These times are quantified as part of MLDTOMF and MLDT above. But if the help desk is a significant part of logistic support, it may be appropriate to have a measure dedicated to highlighting the usefulness of it.

4.3 LOG DEMOS

Consideration may be given to performing a Logistics Demonstration (Log-Demo) as part of IOT&E or FOT&E, once the LCSP has been fully implemented. Log-Demos are appropriate to verify or validate packing, handling, and storage of equipment. They may also be useful in supplementing the evaluation of the adequacy, utility, and storage of pack-up kits. Although not all programs have the resources to support it, exercising the supply system, by spot-checking the response time for specific critical parts can provide valuable insight into the adequacy of the logistic support system. Log Demos are often executed in conjunction with maintenance demonstrations.

4.4 TEST LIMITATIONS

Logistic Supportability is often the most difficult Suitability COI to evaluate due to limitations often experienced in testing. As discussed earlier in this chapter, many programs do not have the full and complete logistic support system in place at IOT&E. This makes it challenging to resolve the COI, and especially difficult to assess risk to IOT&E during an OA or EOA. A limitation to test should be included in the test report if a non-operationally representative logistic support environment exists. The most common limitations are listed below:

- The MSD has been delayed beyond IOT&E.
    - This is at least a major limitation; the true logistic support structure cannot be evaluated fully. If parts are being provided via temporary means, it might be useful to measure LDT and discuss the applicability of the results in the report. However, one might be left with only qualitative aspects to evaluate.
    - If the aspects which one can evaluate demonstrate enough problems, then one might be able to evaluate the COI as UNSAT.
    - The COI can be resolved SAT, but only with sufficient data gathering on the supply chain's progress toward, and risk to supporting system availability at/after MSD.
    - If the limitation is severe and the COI is UNRESOLVED, this will result in a recommendation to evaluate Logistic Supportability in a future test period.
- Parts were provided in a way inconsistent with the LCSP (see paragraph 4.1.5).
    - When these situations arise, the balance between the efficiency of effectiveness testing and an adequate Logistic Supportability evaluation must be considered.
    - Limitation severity is dictated by the availability of data to estimate LDTs.

It is important to draw a distinction between a delayed MSD and an inadequate logistic support system. If the MSD is delayed (formally) beyond IOT&E, this essentially represents a deferment of capability. Therefore, logistic support may be challenging to evaluate fully, resulting in a limitation to test. With NAVSUP support however, it is still possible (and encouraged) to resolve the COI. If the logistic support system is not adequate with respect to where it should be for IOT&E (or even an OA), meaning logistic resources are not yet in place, documentation has not been provided, training has not been developed, etc.; then the COI may be UNSAT or represent a high risk to IOT&E.

4.5 DEFICIENCIES

If there are significant delays in returning the SUT to operational status attributable to off-board logistics delay time, or in general, to the logistics concept, these problems should be documented via a Blue Sheet.

The litmus test, to determine if a potential problem is a formal issue (i.e., deficiency or risk), is whether it negatively affects, or has the potential to affect, Availability.

The problem statement of the Blue Sheet (paragraph 1) should briefly describe the failure and details of the logistic supportability issues encountered, rather than state an unsatisfactory MLDTOMF was observed. The deficiency may manifest as an increased MLDTOMF or decreased A_O; however, the issue is in parts not being accessible, on hand, etc. Failed measures are not a deficiency in and of themselves. These numbers (MLDTOMF) are more appropriately included in the results paragraph as a discussion item of overall impact of deficiencies to downtime and subsequently to Availability. Paragraph 2 should include a discussion of what contributed to the logistics delay time, such as:

- The logistics concept did not include adequate onboard spares,
- Logistics parts procurement was inadequate (e.g., too few parts built and/or procured),
- Inconsistent or incorrect documentation delayed spares being provided.

The mission relation of these issues will be their impact on Availability. Adversely impacting Availability means downtime was increased to such an extent that it did not support mission accomplishment. If this is the case, then Availability should be listed as an "Other Affected COI" in paragraph 1(b) of the Blue Sheet. Due to the impact to mission accomplishment, it is recommended strong consideration be given to categorizing the Blue Sheet at or above the Major 3 level.

4.6 EVALUATING LOGISTIC SUPPORTABILITY RESULTS

In answering the fundamental question: "Will the [SUT] be logistically supportable?" one must understand how well the logistic system is designed to support the Availability of the SUT. Just like Reliability and Maintainability, Logistic Supportability cannot be based solely on threshold assessments. Does the LCSP support the system when deployed in the intended operational environment? Does it support the required Availability of the system? These are fundamental questions, which must be answered.

Remember, in the results section of the report, there needs to be a discussion of the impact of Logistic Supportability on the Availability of the SUT. Quantitative results are important, in that they provide useful information about how long logistics actions take. However, they only have meaning in how they relate to Availability. When thresholds exist, those assessments are informative, but the mission relation to system Availability needs to be understood. Consider the following (at a minimum) when discussing results:

- Were there significant delays in returning the SUT to operational status attributable to off-board logistic delay time?
- Were certain critical parts difficult to obtain? What was their effect on downtime?
- Did the provided onboard spares support the observed failure rates?
- Were APL/AELs not available, not complete, or not correct?
- Was the onboard supply able to keep up with the pace of repairs?

In the end, is the sustainment concept, as implemented under the LCSP, adequate in supporting system Availability? This should form the basis of the Logistic Supportability evaluation.

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5.1 DISCUSSION

Availability is the readiness of a SUT to start and/or continue a mission. More technically, Availability is a measure of the degree to which the SUT is operable, and can be committed, when the mission is called for at an unknown (random) point in time[27].

The concept of being "mission capable" is straightforward for a SUT having a single mission area. Therefore, it makes sense to represent Availability with a single measure, Operational Availability (A_O). However, a multi-mission SUT requires additional measures to characterize Availability fully: Full Mission Capable (FMC), Partial Mission Capable (PMC), and Mission Capable by Mission Area (MC_{MA}).

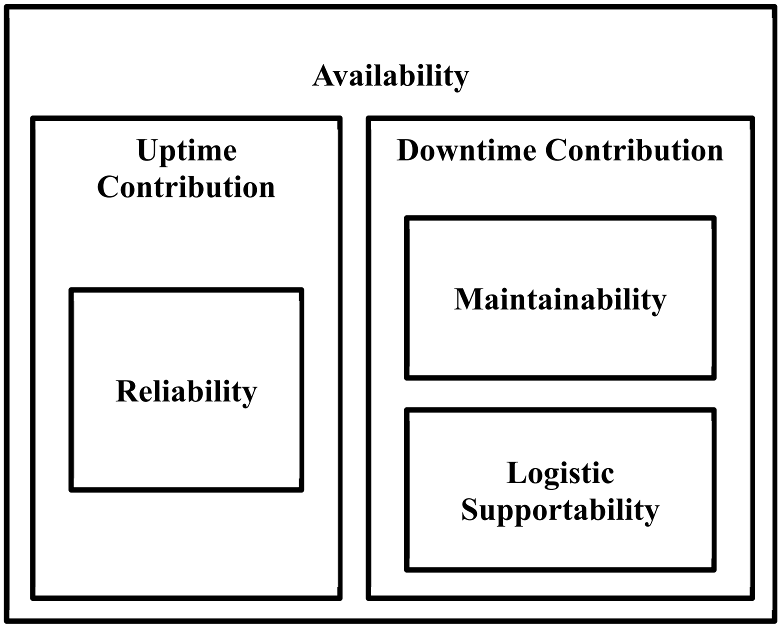
OPNAVINST 3000.12A states the Office of the Chief of Naval Operations (OPNAV) Resource Sponsor must document A_O as a Key Performance Parameter (KPP). Therefore, A_O shall be evaluated in all IOT&E and FOT&E periods. Additional measures of Availability exist, such as Inherent Availability (A_i) and Achieved Availability (A_a) (see paragraph 5.2.1.3 for definitions). These measures are not ideal for evaluating Availability in IOT&E and FOT&E, as they do not address Logistic Supportability, one of the fundamental elements of Availability. However, they may be useful for assessing Availability during an EOA, OA, or an IOT&E prior to the MSD. These measures may be used best as a mitigation to inform decision makers when the immaturity of logistics or maintenance causes a limitation to test.

5.1.1 The Fundamental Elements of Availability

As discussed in chapter 1, Reliability, Maintainability, and Logistic Supportability (RM&L) are the fundamental elements of Availability. As such, the positive and negative impacts of RM&L shall be discussed in the Availability COI results paragraph. RM&L are discussed in chapters 2, 3, and 4 respectively. The effects of RM&L collectively contribute to the available and non-available time of a SUT (figure 5-1), subsequently impacting the Availability for one or more missions. For continuously operated systems, Reliability (measured by MTBOMF) characterizes uptime, while Maintainability (MCMTOMF) and Logistic Supportability (MLDTOMF) are downtime components of Availability.

[27] DAU Glossary, https://www.dau.mil/glossary/pages/1469.aspx.

Figure 5-1. Fundamental Elements of Availability (Basic)



It follows from the subordinate relationship of RM&L to Availability, that a deficiency shall not have a "Primary COI" of Availability. Availability issues exist only through RM&L deficiencies that affect Availability. Therefore, Availability may only be listed as an "Other Affected COI."

5.2 MEASURING OPERATIONAL AVAILABILITY (A_O)

OPNAVINST 3000.12A[28] discusses multiple methods of calculating A_O. Two of these methods are discussed below. Of the two methods discussed, *Measured* availability is used at OPTEVFOR to assess operational availability, as opposed to Projected availability which is generally not used.

Operational Availability (A_O) (Projected)

For continuous-use systems, it suggests calculating A_O using the following formula:

$$A_O = \frac{MTBF}{MTBF+MTTR+MLDT}$$

For intermittent-use systems, it suggests using one of the two formulae presented as follows:

[28] OPNAVINST 3000.12A, Operational Availability of Equipment and Weapons Systems, 2 September 2003.

For aircraft:

$$A_O = 1 - \frac{MTTR+MLDT}{K\prime(MTBF)}$$

Where K' is defined as total calendar time over total operating time. It is the inverse of the proposed utilization rate.

For ships:

$$A_O = \frac{K\prime\prime(MTBF)}{K''(MTBF)+MTTR+MLDT}$$

Where K'' is defined as:

$$K'' = K' - \frac{MTTR+MLDT}{MTBF}$$

Each of these formulae attempts to represent the determining elements of Availability via MTBF (Reliability), MTTR (Maintainability), and MLDT (Logistic Supportability). This calculates A_O, based on the means measured in test, and accounting for OPTEMPO via "K factors." Assuming one were to use these with OMF-related measures (i.e., MTBOMF, MCMTOMF, and MLDTOMF), it still may not be sufficient for four reasons:

- The predicted A_O formula does not account for onboard/on station administrative maintenance delays (MDT) that increase downtime.
- It does not account for downtime caused by preventive maintenance.
- MLDTOMF considers only the number of OMFs, which required off-board logistic support, vice the total number of OMFs that caused downtime to occur.
- This formula only works for successive failures, and does not accurately account for concurrent maintenance or logistic actions.

Operational Availability (Measured)

For simplicity and accuracy, it is recommended to use the basic A_O formula below for continuous-use and intermittent-use systems.

$$A_O = \frac{Uptime}{Uptime+Downtime} \qquad \text{(Formula 5-1)}$$

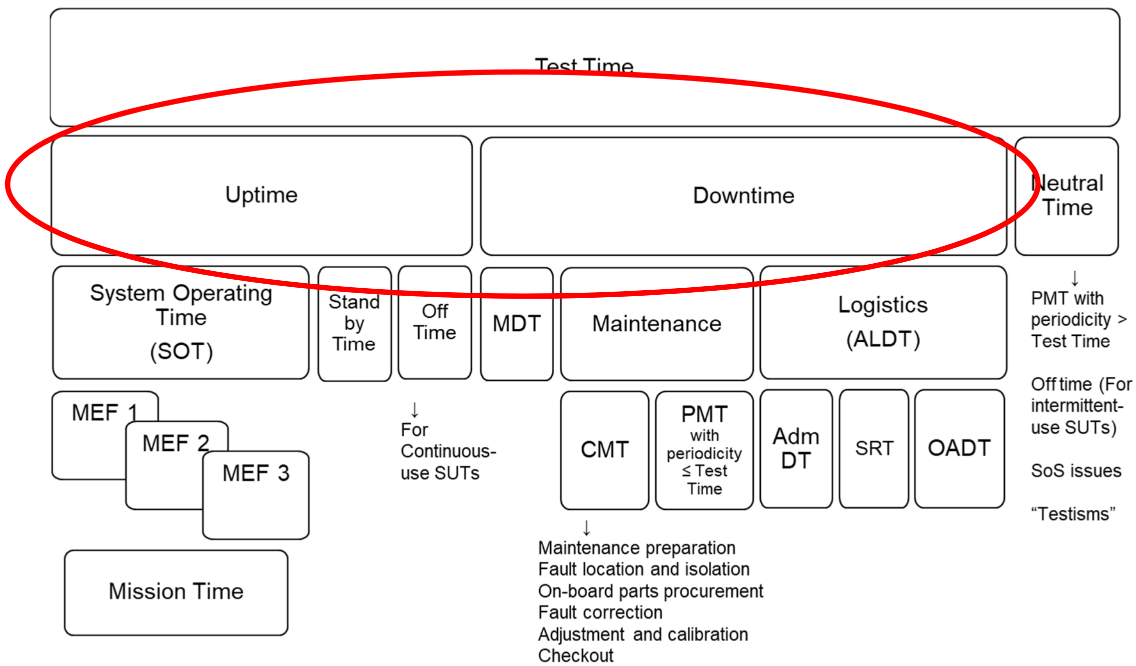
This basic ratio of uptime to total time experienced in test is the most accurate measure of Availability, if the SUT was tested under operationally realistic conditions. It avoids the issues discussed above, and enables inclusion of all the uptime and downtime elements, depicted in figure 5-2 (see example in section 5.3). This formula is expanded-upon in the next few sections.

The next few sections discuss quantitative measures, and how they can be used to support an understanding of Availability. The following discussion of measures should be used in conjunction with Appendix D of this handbook, which includes specific DRs for each measure.

5.2.1 Duty Cycle Considerations

Recall from chapter 1 that many forms of "time" help to characterize Availability, and the fundamental factors affecting RM&L. For Availability, one should focus on the second level, depicted in figure 5-2.

Figure 5-2. Fundamental Elements of Availability (Detailed)



For simple systems, selection of a specific formula should be based on the duty cycle and the operational concept of the SUT or subsystem. As stated above, formula 5-1 should be used for *continuous-use* and *intermittent-use* systems.

For each of these duty cycles, the definition of *uptime* is important, which is slightly different for each. The difference is in the treatment of off-time. Recall from chapter 1:

- System Operating Time (SOT) – The time the system was on, and being stressed under operational loads.
- Standby Time (ST) – When the system is energized, but not operating in performance of a mission.

- Off Time – When the system was not operating, but assumed to be operational[29]. *For intermittent-use systems, off time is not a component of system uptime. Only SOT and ST should be included.*

Below is a breakdown of formula 5-1 for each of these duty cycles:

- For continuous-use systems:

$$A_O = \frac{(SOT+ST)+Offtime}{(SOT+ST)+Offtime+Downtime} \qquad \text{(Formula 5-2)}$$

- For intermittent-use systems:

$$A_O = \frac{(SOT+ST)}{(SOT+ST)+Downtime} \qquad \text{(Formula 5-3)}$$

Downtime is composed of:

- MDT is accrued when the system is down but maintenance and/or logistics actions are not actively being performed.
- CMT is the total corrective maintenance time required to perform the following six sub-components for OMFs: (1) maintenance preparation, (2) fault location/isolation, (3) onboard parts procurement, (4) failure/fault correction, (5) adjustment and calibration, and (6) checkout/quality assurance. It is advisable to identify the start, stop, and total time for each of the six CMT sub-components to support post-test analysis and reporting.
- PMT is the total time required to perform the following five sub-components: (1) maintenance preparation, (2) onboard parts procurement, (3) correction, inspection, servicing, (4) adjustment and calibration, and (7) checkout/quality assurance. It is included only when the maintenance requires the SUT to be taken down/off-line rendering it unavailable. PMT that is of a periodicity less than or equal to the test duration time is considered downtime, and is included in the A_O calculation. PMT that is of a periodicity greater than the test duration is considered neutral time, and is not included in the A_O calculation.
- ALDT is the portion of downtime caused by administrative and logistic reasons. This is the time spent waiting for maintenance personnel, transportation, remote technical support, additional training or documentation, and off-board or off-station parts, while the SUT is down or unavailable.

On-Demand Availability (A_{OD})

A_{OD} (formula 5-4) should be used for on-demand or impulse systems.

$$A_{OD} = \frac{Number\ of\ times\ the\ systems\ was\ available}{Number\ of\ times\ the\ systems\ was\ required} \qquad \text{(Formula 5-4)}$$

[29] Use of neutral time should be considered for offtime where the OPTEMPO experienced during testing is significantly less than expected for Fleet use of the SUT.

For *on-demand* or *impulse* system availability, it is important to understand specifically when it is being measured. Typically, it is measured before system use. For example, Availability usually is measured for an aircraft missile system each time a demand signal occurs, and spans the breakout, inspection, upload, and BIT check of the weapon. If the weapon passes all of these checks, it is considered available for the missions. Then Reliability is measured after this point, assessing whether a HW failure or SW fault occurred during use of the missile.

Because each SUT is unique, the calculation methodology should take its configuration into consideration. It should also explicitly consider redundancies in mission capability and the duty cycles of the mission-critical subsystems. Work closely with 01B and 01C representatives to determine how the SUT's configuration will impact measure selection and analysis. This should be accomplished prior to In Process Review (IPR)-1 in the MBTD process to ensure developed measures and supporting DRs are appropriate for the SUT's duty-cycle.

5.2.1.1 Neutral Time

Situations can arise during testing, which require the use of neutral time. During this time, the SUT is neither accruing uptime nor downtime (figure 5-2). Neutral time should be assigned for situations, which do not allow for a fair measurement of SUT Availability. Therefore, it is not included in Availability calculations. Typical situations include:

- Off time, except for continuous-use systems, where it is included in uptime
- PMT when the periodicity[30] of preventive maintenance is greater than the total test time.
- System of Systems (SoS) issues that preclude operation of the SUT.
- Situations, where use of the SUT does not represent fleet OPTEMPO. This is particularly important for continuous-use systems, when maintenance or logistics actions are halted for reasons unique to the test environment.
- Any situation, in the judgment of the OTD, the test departs from operational realism, such that the measure of Availability is not fair.

Neutral time should be applied judiciously, and all instances of it must be confirmed during the OTSB.

5.2.1.2 Mission Complexity Considerations

For a simple SUT, A_O (or A_{OD}) is the primary quantitative measure. However, for complex, multi-mission SUTs, such as aircraft, ship, or submarine platforms, it is generally more meaningful to report Availability from a mission area perspective (e.g. SUW). Therefore, the primary quantitative measures of Availability for multi-mission systems are FMC, PMC, and MC_{MA}. A_O or A_{OD} may also be reported for a complex system, if it is specified in the requirements document.

[30] For example, if a SUT requires different conditional inspections at one-, three-, and six-month intervals, and the test phase is two months long, only downtime due to the one-month inspections will count toward Availability calculations.

Full Mission Capable (FMC)
FMC (formula 5-5) is defined as the material condition of a SUT in which it can perform all of its missions[31]. Although it is analogous to A_O (formula 5-1), in this case "uptime" is defined as the total time the SUT is capable of performing all of its missions.

$$FMC = \frac{Uptime_{FMC}}{Uptime_{FMC}+Downtime_{FMC}} \qquad \text{(Formula 5-5)}$$

Partial Mission Capable (PMC)
PMC (formula 5-6) is defined as the material condition of a SUT in which it can perform at least one of its missions[33]. It is calculated similarly to A_O (formula 5-1). However, PMC uptime is the time the SUT is capable of performing at least one of its missions. Note PMC uptime includes FMC uptime. The MCSM (table 1-1) is important in helping to determine whether a given subsystem casualty renders a mission area not mission capable, while others are still capable.

$$PMC = \frac{Uptime_{PMC}}{Uptime_{PMC}+Downtime_{PMC}} \qquad \text{(Formula 5-6)}$$

Mission Capable by Mission Area (MC_{MA})
Availability can be further broken down into mission areas for multi-mission SUTs. MC_{MA} (formula 5-7) is a measure of the system's capability to perform a specified mission. It is calculated similarly to A_O (formula 5-1); however, MC_{MA} uptime is the time the SUT is capable of performing a specific mission (i.e., replace "MA" with the name of the actual mission/COI). Note the subsystems relevant to each mission area, should be defined when assessing Reliability, as indicated in table 1-1. It is recommended to use MC_{MA} in a consistent way with other COIs (e.g., R_{MA}).

$$MC_{MA} = \frac{Uptime_{MA}}{Uptime_{MA}+Downtime_{MA}} \qquad \text{(Formula 5-7)}$$

While the formulae for FMC, PMC, and MC_{MA} appear to be very similar, the distinction is how uptime and downtime are defined for each formula.

5.2.1.3 SUT Maturity Considerations

Ideally, A_O would provide the most realistic measure of Availability of a simple SUT operating in a combat environment. However, the impacts of logistic support and maintenance on Availability are difficult to estimate during test. There may be factors that preclude a fully meaningful measure of A_O. These situations are most often experienced during EOAs and OAs. They include non-representative logistic support (i.e., not representative in areas of priority, timing, or location), logistic support system immaturity, and non-representative maintenance (i.e., preventive and/or corrective). When conducting an EOA or OA and faced with an immature maintenance plan or logistic support plan, not yet fully realized; it may make more

[31] Memorandum of Agreement on Multi-service Operational Test and Evaluation (MOT&E) and Operational Suitability Terminology and Definitions, September 2020.

sense to measure Achieved or Inherent Availability, instead of A_O. These measures may be used to inform decision makers, when the immaturity of logistics or maintenance causes a limitation to test.

Achieved Availability (A_a)

A_a (formula 5-8) is the Availability of a system with respect to operating time and both corrective and preventive maintenance. It excludes Offtime, MDT, Standby Time, and ALDT. A_a is normally used as a hardware-oriented measure primarily during DT and initial production testing, when the system is not operating in its intended support environment.

$$A_a = \frac{SOT}{SOT + (Downtime\ due\ to\ CMT\ \&\ PMT\ only)} \qquad \text{(Formula 5-8)}$$

Note: Total downtime may not equal the sum of all CMT and PMT.

Inherent Availability (A_i)

A_i (formula 5-9) is the Availability of a system, with respect to only operating time and corrective maintenance. It excludes Offtime, MDT, Standby Time, PMT, ALDT. A_i is a poor estimate of true combat potential for most systems, because it provides no indication of the time required to obtain necessary field support. However, it can be useful in determining basic operational characteristics, under stated conditions in an ideal customer service environment.

$$A_i = \frac{SOT}{SOT + (Downtime\ due\ to\ CMT\ only)} \qquad \text{(Formula 5-9)}$$

Note: Total downtime may not equal the sum of all CMT.

5.2.2 Material Availability (A_M)

According to the DoD RAM-C Manual[32], the Availability KPP is composed of two components: Materiel Availability (A_M) (Fleet), and A_O (unit). These two components provide Availability percentages from a corporate, Fleet-wide perspective and an operational unit level, respectively. Although understanding A_M is integral to understanding the KPP, there are challenges in measuring it in OT.

A_M is a measure of the percentage of the total inventory of a system operationally capable (ready for tasking) of performing an assigned mission at a given time, based on materiel condition. This measure can be expressed mathematically, as a number of operational end items/total population. A_M addresses the total population of end items, planned for operational use, including those temporarily in a non-operational status, once placed into service (such as for depot-level maintenance). The total life cycle time frame, from placement into operational service through the planned end of service life, must be included. Development of the A_M metric is a program manager responsibility. Based on this, A_M cannot and should not be measured in OT. It would require access to the entire population of fleet systems, with an ability to assess their Availability.

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[32] Department of Defense Reliability, Availability, Maintainability, and Cost Rationale Report Manual, 1 June 2009.

5.3 EXAMPLE

Building on the example presented in chapter 3 (section 3.2.1.4), recall the SUT is a continuous-use system. It was evaluated during an approximately 6-week test period and experienced multiple OMF_{HW} and OMF_{SW} resulting in numerous periods of downtime. In addition to CMT, several of the OMF_{HW} required off-board logistics support, with most incurring at least some AdmDT.

Calculate Operational Availability (A_O) using the data set in table 5-1:

Table 5-1. (SAMPLE) Availability Supporting Data Table

Uptime				Downtime						
System Operating Time (SOT)			OMF (HW/SW)	Start Downtime (Date, Time)	Corrective Maintenance Time (CMT)		Admin and Logistic Delay Time (ALDT)		Stop Downtime (Date, Time)	TOTAL (min)
Start (Date, Time)	Stop (Date, Time)	TOTAL (min)			HW CMT (min)	SW CMT (min)	LDT (min)	AdmDT (min)		
1/10/2019 0:00	1/13/2019 15:50	5270	SW	1/13/2019 15:50		60			1/13/2019 16:50	60
1/13/2019 16:50	1/16/2019 9:00	2410	HW	1/16/2019 9:00	36			70	1/16/2019 10:46	106
1/16/2019 10:46	1/18/2019 11:46	2940	HW	1/18/2019 11:46	150		1110		1/18/2019 8:46	1260
1/18/2019 8:46	1/24/2019 9:00	8654	SW	1/24/2019 9:00		80			1/24/2019 10:20	80
1/24/2019 10:20	1/25/2019 9:00	1360	HW	1/25/2019 9:00	30			45	1/25/2019 10:15	75
1/25/2019 10:15	1/26/2019 12:15	1560	SW	1/26/2019 12:15		45			1/26/2019 13:00	45
1/26/2019 13:00	2/2/2019 7:29	9749	SW	2/2/2019 7:29		117			2/2/2019 9:26	117
2/2/2019 9:26	2/3/2019 8:36	1390	HW	2/3/2019 8:36	24		2265		2/4/2019 22:45	2289
2/4/2019 22:45	2/4/2019 23:29	44	SW	2/4/2019 23:29		7			2/4/2019 23:36	7
2/4/2019 23:36	2/5/2019 0:46	70	SW	2/5/2019 0:46		1			2/5/2019 0:47	1
2/5/2019 0:47	2/5/2019 20:37	1190	SW	2/5/2019 20:37		6			2/5/2019 20:43	6
2/5/2019 20:43	2/9/2019 0:32	4549	HW	2/9/2019 0:32	50			100	2/9/2019 3:02	150
2/9/2019 3:02	2/9/2019 23:21	1219	HW	2/9/2019 23:21	150		2545		2/11/2019 20:16	2695
2/11/2019 20:16	2/12/2019 18:24	1328	SW	2/12/2019 18:24		4			2/12/2019 18:28	4
2/12/2019 18:28	2/13/2019 9:08	880	SW	2/13/2019 9:08		11			2/13/2019 9:19	11
2/13/2019 9:19	2/15/2019 20:08	3529	SW	2/15/2019 20:08		5			2/15/2019 20:13	5
2/15/2019 20:13	2/16/2019 10:12	839	HW	2/16/2019 10:12	10			40	2/16/2019 11:02	50
2/16/2019 11:02	2/16/2019 12:58	116	SW	2/16/2019 12:58		20			2/16/2019 13:18	20
2/16/2019 13:18	2/17/2019 22:37	1219	HW	2/17/2019 22:37	12		935		2/18/2019 14:24	947
2/18/2019 14:24	2/18/2019 23:53	569	SW	2/18/2019 23:53		11			2/19/2019 0:04	11
2/19/2019 0:04	2/19/2019 0:39	35	SW	2/19/2019 0:39		5			2/19/2019 0:44	5
2/19/2019 0:44	2/19/2019 8:03	439	SW	2/19/2019 8:03		20			2/19/2019 8:23	20
2/19/2019 8:23	2/19/2019 9:35	72	SW	2/19/2019 9:35		73			2/19/2019 10:48	73
2/19/2019 10:48	2/20/2019 6:06	1158	HW	2/20/2019 6:06	10				2/20/2019 6:16	10
2/20/2019 6:16	2/21/2019 15:04	1968	HW	2/21/2019 15:04	20			75	2/21/2019 16:39	95
2/21/2019 16:39	2/21/2019 22:58	379	SW	2/21/2019 22:58		18			2/21/2019 23:16	18

Table 5-1. (SAMPLE) Availability Supporting Data Table											
Uptime			**OMF (HW/SW)**	**Downtime**							
System Operating Time (SOT)				**Start Downtime (Date, Time)**	**Corrective Maintenance Time (CMT)**		**Admin and Logistic Delay Time (ALDT)**		**Stop Downtime (Date, Time)**	**TOTAL (min)**
Start (Date, Time)	**Stop (Date, Time)**	**TOTAL (min)**			**HW CMT (min)**	**SW CMT (min)**	**LDT (min)**	**AdmDT (min)**		
2/21/2019 23:16	2/22/2019 1:51	155	SW	2/22/2019 1:51		10			2/22/2019 2:01	10
2/22/2019 2:01	2/24/2019 2:11	2890	HW	2/24/2019 2:11	150		525		2/24/2019 13:26	675
2/24/2019 13:26	2/25/2019 1:31	725	SW	2/25/2019 1:31		20			2/25/2019 1:51	20
2/25/2019 1:51	2/25/2019 19:08	1037	HW	2/25/2019 19:08	24		336	45	2/26/2019 1:53	405
2/26/2019 1:53	2/27/2019 6:09	1696	HW	2/27/2019 6:09	50			50	2/27/2019 7:49	100
2/27/2019 7:49	3/2/2019 3:07	2598								
Totals		**62037**			**716**	**513**	**7716**	**425**		**9370**

Solution:

Use the continuous-use SUT Availability formula:

$$A_O = \frac{Uptime}{Uptime + Downtime} \qquad \text{(Formula 5-1)}$$

Recall, for a continuous-use SUT, *Uptime* is the total time the system is operating, in standby, or off but assumed to up. *Downtime* is the total time the system is not operational (i.e., down for maintenance or logistics reasons) and cannot be called upon to support mission execution. In this case, there is no standby time or offtime (where the SUT is up), and downtime is comprised of only corrective maintenance time, logistic delay time, and administrative delay time.

$$Uptime = SOT = 62037\ minutes$$

$$Downtime = 9370\ minutes$$

$$A_O = \frac{62037\ min}{62037\ min + 9370\ min} = 0.87$$

What if one wants to measure Predicted Availability? First, calculate MTBOMF, MCMTOMF, and MLDTOMF.

$$MTBOMF = \frac{Total\ System\ Operating\ Time}{Number\ of\ OMFs} \qquad \text{(Formula 2-1)}$$

$$MTBOMF = \frac{62037\ min}{31} = \frac{1033.9\ hours}{31} = 33.4\ hours$$

$$MCMTOMF_{SYS} = \frac{Total\ Elapsed\ Time\ to\ Correct\ OMFs}{Total\ Number\ of\ HW\ and\ SW\ OMFs} \qquad \text{(Formula 3-4)}$$

$$MCMTOMF_{SYS} = \frac{1229\ min}{31} = \frac{20.5\ hours}{31} = 0.7\ hours$$

$$MLDTOMF = \frac{Total\ Elapsed\ Time\ SUT\ is\ Awaiting\ Offboard\ Logistics\ to\ Correct\ OMFs}{Total\ Number\ of\ OMFs\ Requiring\ Off{-}board\ Logistics\ Actions} \text{(Formula 4-1)}$$

$$MLDTOMF = \frac{128.6}{6} = 21.4\ hours$$

Then calculate Predicted Availability using the following formula:

$$A_O = \frac{MTBOMF}{MTBOMF + MCMTOMF + MLDTOMF}$$

$$A_O = \frac{33.4\ hours}{33.4\ hours + 0.7\ hours + 21.4\ hours} = 0.60$$

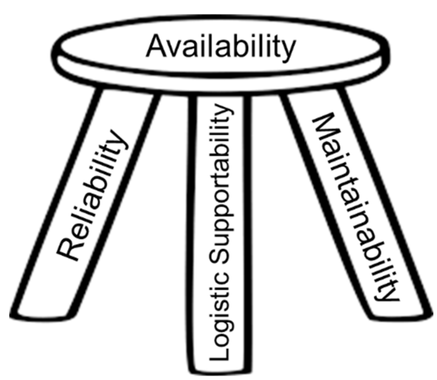
In this case, there are no concurrent failures, but the formula does not take the 7.1 hours of AdmDT into account, nor does it properly weight the effect of LDT (i.e., only six maintenance actions required off-board logistic support). The first result (0.87) is clearly the better measurement of A_O.

5.4 EVALUATING AVAILABILITY

Using logic similar to the other three COIs, where the resolutions or risk assessments should not be driven solely by threshold, the evaluation of Availability should not be determined solely by the comparison of A_O (or A_{OD}) to its threshold. An assessment of whether the measured Availability is sufficient to support mission accomplishment must be made. If the threshold was poorly derived, either not properly accounting for the Reliability needed to support mission accomplishment or developed with a limited understanding of mission needs based on draft CONOPS; then the burden falls on the test team to describe why an A_O (or A_{OD}) that passed threshold is insufficient.

When evaluating Availability, one must discuss the contribution of the other three primary COIs (Reliability, Maintainability, and Logistic Supportability), whether the contribution was positive or negative. As discussed in chapter 1, one cannot understand the factors influencing Availability without an understanding of the three legs of the stool. Recall figure 1-2.

Figure 1-2. The Three-Legged Stool Relationship



In the end, this relationship must be supported both conceptually and mathematically. That is why great care should be taken during the test design process to ensure measures selected to evaluate the four COIs are not disjointed. In fact, they should complement one another in such a way as to support the stool concept.

In the results section of the final report, each of the three legs must be addressed with respect to the level Availability is positively or negatively supported by them, similar to how each of the other COIs must address the level to which they support or degrade Availability.

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6.1 BACKGROUND

The purpose of this chapter is to describe a general method for Fleet Suitability Data Collection, outside of dedicated test periods for SUTs, where available test time may not be sufficient to fully evaluate SUT Reliability. Data collection opportunities outside dedicated test periods may also provide Maintainability, Logistic Supportability, and Availability data to supplement the SUT suitability evaluation.

OPTEVFOR historically has faced challenges in testing acquisition programs with high reliability requirements and limited test resources. Some newer acquisition programs are being developed to meet MTBOMF thresholds that exceed 2,500 hours. For such a system, 7,500 hours of testing (approximately 300 days) is required to test that a typical SUT meets its reliability threshold with 80 percent confidence (assuming one OMF during test). SUTs with high reliability requirements, short mission durations, and/or limited resources should supplement OT data with OT qualified Fleet suitability data to evaluate SUT suitability adequately.

6.2 APPLICATION

When circumstances allow, OT teams should consider gathering Fleet suitability data outside of dedicated test periods to increase the total system operating hours and/or failures available for scoring to support reliability analysis and adequacy of the suitability evaluation. These data can be collected and used for SUT suitability evaluation, if the following data pedigree[33] are met:

1. System configuration remains unchanged between the Fleet Suitability Test Event and the dedicated test period[34].
2. Operationally representative operational tempo.
3. Operationally representative, qualified, and proficient operators[35] and/or maintainers[36].
4. Operationally representative environment.

A Data Collection Plan (DCP) will serve as the plan for gathering all Fleet suitability data prior to the start of a dedicated test phase. The IEF, test plan, and test report should address these Fleet suitability test events of opportunity. Within the MBTD process, suitability measures, DRs, tasks, vignettes, and limitations, associated with these test events, are addressed at IPR-2. The IEF section 3.2 OT vignette strategy should include an OT vignette for suitability data collection, tailored for the measures and DRs, required for the respective Fleet Suitability Test Event. These vignettes, measures, and DRs will be used to create a test event for Fleet Suitability Data Collection in the DCP. Fleet Suitability data qualified for use in OT and gathered prior to the start of OT should be identified in section 2.4 of the dedicated test period's test plan as shown in table 6-1. Fleet Suitability data should supplement OT data using the

[33] The pedigree of the data is important to demonstrate the relevance of the additional Fleet data in comparison to the dedicated test period.
[34] If the system configuration is changed, the test team must prove the changes do not affect the pedigree of the data in order to combine the Fleet and dedicated test period suitability data in the test report.
[35] Operationally representative operators are required to supplement the reliability, maintainability, and/or availability COI evaluations with the additional data collected outside of IOT&E.
[36] Operationally representative maintainers are required to supplement the maintainability and availability COI evaluations with the additional data collected outside of IOT&E.

considerations discussed in chapter 2, and collected during the dedicated test period for analysis in the post-test data analysis summary.

Table 6-1. (SAMPLE) Previous Data Qualified for OT

Event	Date/Location	Measures Fully Satisfied	Measures Partially Satisfied	Operating Hours Collected
Pre-IOT&E RML&A	Jan 1 – Mar 15 2015 / USS SHIP	None	M60 – $MTBOMF_{HW}$ M61 - $MTBOMF_{SW}$ M63 – $MCMTOMF_{HW}$ M64 – $MCMTOMF_{SW}$ M70 – MLDTOMF M75 - A_O	500 hours
Pre-IOT&E R&A	Nov 10 2015 – Feb 20 2016 / USS SHIP, USS SUBMARINE	None	M60 – $MTBOMF_{HW}$ M61 - $MTBOMF_{SW}$ M75 - A_O	3,275 hours

For severe limitations, the test plan may include a test period to continue collecting Fleet suitability data after the dedicated test period. In these cases, the Operational Test Agency (OTA) Evaluation Report (OER) will be published with the respective COI(s) unresolved, and Operational Suitability not evaluated. After all Fleet data are collected and analyzed, an addendum may be published, amending the OER to include the remaining Fleet data, analysis, COI resolution, and Operational Suitability evaluation.

6.2.1 Planning Considerations

Fleet operators and maintainers do not necessarily track SUT failures to the same degree of accuracy as required in OT. The following process to plan and execute Fleet suitability data collection, outside dedicated test periods, should be used to align the accuracy and pedigree of Fleet and OT suitability data:

1. Test team determines the total number of operating hours required.
2. Test team determines the total number of platforms that will receive SUT installation or number of platforms available for testing.
3. Test team identifies sufficient test events of opportunity that meet the data pedigree listed on page 6-1.
4. Test team develops OTSB procedures, ground rules, failure definitions (e.g. hardware and software failures, relevant and non-relevant failures), and data validity methodology for all applicable suitability measures to ensure pedigree of the data is operationally relevant.
5. Test team determines whether OPTEVFOR testers, adjunct testers, or a combination of the two[38] will be used to collect the data.
6. Test team develops a Suitability Data Collection Sheet[39], tailored to collect only the DRs within the scope of the test event. A sample data sheet is provided below in 6.3. Event codes should be tailored to the specific measures and failure definitions, identified in step 4 above for each SUT test event.

[38] Platform level programs that require additional suitability data to resolve COIs or make an operational suitability determination should plan for sufficient resources to cover the number of OPTEVFOR or adjunct testers required.
[39] Ensure the classification of the data collection sheet when filled in by the adjunct tester or data collector is per the SUT SCG as determined in step 4.

Additionally, automated data collection techniques (e.g. Asset Logistics and Maintenance System) may be used, instead of manually collecting the suitability data.

7. Test team determines a coordination schedule with Fleet asset(s) to review data collection efforts, make any data collection adjustments, and answer any questions. The frequency of the coordination schedule will be unique to each SUT and should minimize errors in data collection, and be executable by all organizations involved in data collection/analysis. A sample coordination schedule is provided in table 6-2 below:

Table 6-2. (SAMPLE) [SUT] [Test Event/Phase] Coordination Schedule

Event	ID	Date	Time	Location	Coordination Method	Description
Pre-IOT&E RML&A (1Jan15 - 30Jan15)	1	1Jan2015 – 4Jan2015	0730-1600 EST	USS SHIP	On-site training	OPTEVFOR OTD will be on-site at USS SHIP to provide data collection training to all applicable data collectors and adjunct testers
	2	5Jan2015 – 10Jan2015	0730-1600 EST ------------- 1800 EST	USS SHIP	On-site daily coordination ----------------------- On-site end of day wrap-up	OPTEVFOR OTD will be on-site at USS SHIP to monitor initial system operation and data collection and address any errors or ambiguities as they arise. -- An end of day wrap-up meeting will ensure representatives from all involved agencies are aware of current data collection status and any errors or ambiguities encountered during that day's operations.
	3	15Jan2015	1500EST	N/A	E-mail	Data collector/Adjunct testers email weekly data collect sheet(s) to OPTEVFOR OTD.
	4	16Jan2015	1500 EST	N/A	Telephone Conference	All agencies will participate in a weekly teleconference for the remainder of the event to discuss the previous week's data collection, errors, and/or any ambiguities in data collection.
	5	23Jan2015	1500 EST	N/A	E-mail	See Description in ID #3.
	6	30Jan2015	1500 EST	N/A	Telephone Conference	See Description in ID #4.

8. OPTEVFOR OTD develops a Memorandum of Agreement (MOA) between OPTEVFOR and the participating Fleet asset(s). A sample MOA is provided in enclosure (2).
9. OTD develops test plan or DCP that documents the previous eight steps, and serves as the plan for gathering all Fleet suitability data.
10. OPTEVFOR OTD travels to participating Fleet asset[40].
11. OTD verifies all data pedigree listed on page 6-1 is met.
12. OTD provides data collection training to the participating operators and maintainers[41].

[40] For lengthy data collection periods, consider travelling to the fleet asset in the middle of the test event to provide additional data collection training (if needed).
[41] During extended data collection periods, the OTD will need to travel to the test platform(s) to provide data collection training to any new adjunct testers that transfer to the test platform(s).

13. OTD provides adjunct test forms to be signed by participating operators and maintainers.
14. OTD conducts first week trial period for data collection.
15. OTD departs Fleet asset.
16. OTD coordinates with adjunct tester and/or OPTEVFOR data collector to review collected data at the frequency determined in step 7.
17. OTD conducts OTSB(s), at the frequency determined during the DCP development.

6.3 SAMPLE FAILURE DATA COLLECTION SHEET

SAMPLE OPTEVFOR SUITABILITY DATA COLLECTION SHEET X-X

Platform:		Data Collection Period:	Start Date	Stop Date
Configuration:				

Date (dd-mmm)	Time (Local)	Event Codes	AT/DC	Component	Description	Individual Steps to Restore

Event Codes:

a. System Power On
b. System in Routine Use
c. System in Standby for use
d. Abnormal Indication
e. Component Failure/Casualty
f. Software Fault
g. Preventive Maintenance Start
h. Preventive Maintenance Stop
i. Corrective Maintenance Start
j. Corrective Maintenance Stop
k. Part Procurement Start
l. Part Procurement Stop
m. System Restart/Reboot Start
n. System Restart/Reboot Stop
o. System Power Off – System ready
p. System Power Off – System Degraded

SAMPLE OPTEVFOR SUITABILITY
DATA COLLECTION SHEET INSTRUCTIONS

The [SUT] Suitability Data Collection Sheet is designed to capture system operating, stand-by, corrective maintenance, part procurement (onboard and off-board), and off times. This data sheet will be submitted to the OPTEVFOR OTD for review and recording on a [frequency determined by coordination schedule] basis. Please refer to the following guidelines when using this data sheet.

1. Annotate the Data Collection Period Start Date and record the status of the equipment in line 1.
2. For each subsequent entry, enter the date and time of the event, the event code(s), initials of the Adjunct Tester (AT) or Data Collector (DC) who observed the event, the component affected, a description of the event, and each individual step required to fix/restore the system to operation.
3. Include as much detail as possible regarding the event description and steps required by the operator/maintainer to restore the system to operation including any applicable conditions, environments, and threats that were encountered for each entry.
4. Because it is often not apparent, log the potential root cause(s) once it has (they have) been determined in the description column.
5. At a minimum, each adjunct tester or data collector should log events at the start and end of their data collection periods per day.
6. At the end of the week, or when the log is complete, annotate the data-collection period stop date.
7. Scan and submit logs weekly to: (OPTEVFOR OTD e-mail) and (OPTEVFOR Operational Test Coordinator (OTC) e-mail).

Please retain physical copies of all data sheets until advised otherwise by OPTEVFOR.

Sample:

Date (dd-mmm)	Time (Local)	Event Codes	AT/DC	Component	Description	Individual Steps to Restore
1-Jan	0800	A	JPJ	N/A	System Power On	N/A
1-Jan	0900	E	CAN	Part A	Loss of LOS Link. Unable to forward local Link tracks to HQ.	Contacted Maintainers per SOP.
1-Jan	0905	I	CAN	Part A	Maintenance Start on Part A	Troubleshoot MIDS-LVT, determined output good. Switched to secondary TNP. Replaced 1553 card and rebooted primary TNP. Returned primary TNP to service.
1-Jan	0925	J	CAN	Part A	Maintenance Stop on Part A	See above steps.
1-Jan	1600	B	JPJ	N/A	Adjunct tester rotation. System on and in routine use	N/A

6.4 SAMPLE MOA

3980
Ser XX/XXX

From: Commander, Operational Test and Evaluation Force
To: [Command]

Subj: MEMORANDUM OF AGREEMENT FOR OPERATIONAL TEST DATA COLLECTION FOR [Insert Name of Program Here] PROGRAM

Encl: (1) Memorandum of Agreement
(2) [Insert Name of Program Here] Reliability Data Collection Log
(3) COMOPTEVFOR Nondisclosure of Information/Adjunct Tester Agreement

1. Request all enclosures be reviewed and enclosure (1) returned either signed or with [Command]'s desired modifications indicated.

2. The point of contact is [Insert OTD Name] [Code XXX] at DSN XXX-XXXX, extension XXXX or commercial (757) 282-5546.

I. M. CAPTAIN
By direction

Copy to:
CNO (N84)
PEO XXXX

DISTRIBUTION STATEMENT ?. See program-specific SCG for the correct distribution statement.

DESTRUCTION NOTICE - For classified doc[...] Section 11 - 19 or DoD 5200.01, DoD Informa[...] method that will prevent disclosure of contents[...]

WARNING - This document contains technica[...] U.S.C., Sec 2751, et seq.) or the Export Admin[...] of these export laws are subject to severe criminal penalties. Disseminate in accordance with provisions of DoD Directive 5230.25.

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NOTE: The Security Classification Guide (SCG) dictates the distribution statement. Use the latest SCG from the Defense Technical Information Center (DTIC) Web site.

DEPARTMENT OF THE NAVY
COMMANDER, [COMMAND]
[CITY], [STATE] ([9-DIGIT ZIP CODE])
COMMANDER, OPERATIONAL TEST AND EVALUATION FORCE
NORFOLK, VA (23505-1498)

[CMD]
3980
Ser XXX/

OPTEVFOR
3980
Ser XX/XXX

MEMORANDUM OF AGREEMENT
BETWEEN
COMMANDER, [COMMAND]
AND
COMMANDER, OPERATIONAL TEST AND EVALUATION FORCE

Subj: MEMORANDUM OF AGREEMENT FOR OPERATIONAL TEST (OT) DATA COLLECTION FOR [Insert Name of Program Here] PROGRAM

Ref: (a) [Insert Name of Program Here] Reliability Data Collection Log
(b) COMOPTEVFOR Nondisclosure of Information/Adjunct Tester Letter

1. This Memorandum of Agreement (MOA) establishes the responsibilities of OPTEVFOR and [CMD] as they relate to operational test data collection during the period of [Start Date] to [End Date] at [Command], [City], [State].

2. The purpose of operational test data collection is to provide a record of hardware reliability over a sufficient number of operating hours to assist in resolution of the reliability Critical Operational Issue and evaluation of operational suitability for [Insert Name of Program Here].

3. OPTEVFOR requests support from [CMD] staff members to collect Reliability data as outlined in reference (a). [CMD] and OPTEVFOR agree to the following procedures:

a. Establishment of Adjunct Testers. [CMD] shall identify personnel to collect data. A sufficient number of personnel shall be identified to ensure data collection occurs as long as the [Insert Name of Program Here] is in use. OPTEVFOR shall provide data collection guidance via reference (a) and establish the personnel as adjunct testers via reference (b).

b. Data Collection. Adjunct testers shall collect data per the guidance provided in reference (a). A weekly data synopsis shall be provided to OPTEVFOR via the data collection sheet enclosed in reference (a).

c. Coordination. A representative of OPTEVFOR and the [CMD] shall participate in a weekly phone conference to address errors or ambiguities in the data collected over the previous week, or make adjustments to the collection methodology as required.

4. Operational test data obtained via this MOA is necessary for the resolution of one or more Critical Operational Issues in the testing of [Insert Name of Program Here]. However, data collection is intended to occur on a not-to-interfere basis with the normal operational functions of the [Insert Name of Program Here].

____________________________	____________________________
ACOS Name, By direction	Program Manager

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APPENDIX A - Reliability Measures and Data Requirements

Purpose: Expand on the detail already provided on reliability in the IEF checklist. The suggested measures and DRs provided below are optional, although a critical measure for Reliability, with respect to OMFs, must be used. They are provided only to start the core team's brainstorming effort, on how to best approach measures and DRs for reliability.

1. Ensure the full scope of SUT reliability is considered in the MBTD.

> ***Reliability has no subtasks. Measures must cover all system operation periods. Data collected must examine the full scope of reliability.***
>
> ***Reliability data can be collected in a stand-alone R/A vignette that is executed in parallel with all other vignettes. The data can also be collected by linking reliability to all vignettes.***

2. Verify the reliability data to be collected will support examination of Availability.

> ***Reliability is the uptime component of availability. It addresses the likelihood the SUT will support mission execution to completion without a failure.***

3. Ensure all terms within reliability calculations are defined/understood.

> ***Operating hours start/stop criteria (continuous), OMF definitions, failure/fault definitions, mission start/complete criteria, critical systems for missions, etc.***

4. Reference the list of suggested reliability measures and DRs.

> ***Measures and DRs, commonly used to address reliability, are provided below. They should be considered for use on all testing efforts. Programs are not required to include all the measures and DRs below, as not all of them will apply to every system. Conversely, these measures and DRs may not cover the full scope of data needed to be gathered for every system. Details, on many of the measures below, can be found in the 2020 OTA MOT&E MOA.***
>
> ***DRs, with no highlighting, should almost always be used with the associated measure. DRs highlighted blue are less commonly used. DRs highlighted gray will probably only apply in unique cases.***

a. **Measure:** Mean Time Between Operational Mission Failure ($MTBOMF_{SYS}$) = total system operating time/number of operational mission hardware failures and software faults. **Criterion:** Ideally, a specified time.

> ***Only include $MTBOMF_{SYS}$ as a non-critical measure if it is a specified metric in the SUT capabilities document. $MTBOMF_{HW}$ and $MTBOMF_{SW}$ are the required critical measures for reliability***

Data Requirement
Date/time start test (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time end test (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time system turned on (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time system turned off (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time system set to standby (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time system out of standby (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time failure/fault occurs (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Hardware failure mode and cause (Qualitative) FROM Maintainer Observation
Software fault description and cause (Qualitative) FROM Maintainer Observation
Mission impact of failure/fault (Qualitative) FROM Operator Observation
Mission impact of failure/fault (Qualitative) FROM OTD Observation
Mission impact of hardware failure frequency (Qualitative) FROM Operator Observation
Mission impact of software fault frequency (Qualitative) FROM Operator Interview
System workload/stress level versus Fleet representative workload/stress level (Qualitative) FROM Operator Interview

Data Requirement
System workload/stress level versus Fleet representative workload/stress level (Qualitative) FROM OTD Observation
Impact of non-representative workload on reliability (Qualitative) FROM Operator Observation
Impact of non-representative workload on reliability (Qualitative) FROM OTD Observation
DT operating time (hh:mm:ss) FROM DT Report
DT operational mission failures/faults (Number) FROM DT Report
DT demonstrated $MTBOMF_{SYS}$ (hh:mm:ss) FROM DT Report
System workload/stress level during DT versus Fleet representative workload/stress level (Qualitative) FROM DT Report
Impact of DT workload on reliability (Qualitative) FROM DT Report
DT hardware failure modes and causes (Qualitative) FROM DT Report
DT software fault descriptions and causes (Qualitative) FROM DT Report
DT assessment of infant mortality effect on test results (Qualitative) FROM DT Report
Highly accelerated life testing results (Qualitative) FROM HALT Report
Component reliability data (Qualitative) FROM DT Report
Component reliability impacts (Qualitative) FROM DT Report
Similar existing system $MTBOMF_{SYS}$ (hh:mm:ss) FROM Fleet Maintenance Data

b. **Measure:** MTBOMF, <Mission Area> ($MTBOMF_{MA}$) = total mission area time/ number of mission area OMF_{HW} and OMF_{SW}.
Criterion: Time.

This measure applies to multi-mission systems. When writing $MTBOMF_{MA}$, replace the "MA" with the mission area abbreviation (AW, ASW, etc.). Adjust the MTBOMF DRs for a single mission area, similar to what is done in adjusting A_O to MC_{MA}.

c. **Measure:** Mean Time Between Failure (MTBF) = total system operating time/ number of hardware failures and software faults.
Criterion: Ideally, a specified time.

Reliability is not just about OMFs. Frequent failures can impact mission execution, even if they are not OMFs. This measure targets the impact of all failures. The DRs for MTBF are the same as those for MTBOMF. The data, collected for both measures, allows scoring of failures/faults as OMFs, which allows analysis of both measures.

d. **Measure:** Mean Time Between Operational Mission Hardware Failure ($MTBOMF_{HW}$) = total system operating time/ number of operational mission hardware failures (OMF_{HW}).
Criterion: Ideally, a specified time.

Hardware and software have different reliability behaviors. Breaking reliability between HW and SW is required. $MTBOMF_{HW}$ should be a critical measure for reliability evaluations.

Data Requirement
Date/time start test (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time end test (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time system turned on (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time system turned off (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time system set to standby (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time system out of standby (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time failure occurs (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Hardware failure mode and cause (Qualitative) FROM Maintainer Observation
Mission impact of failure (Qualitative) FROM Operator Observation
Mission impact of failure (Qualitative) FROM OTD Observation
Mission impact of hardware failure frequency (Qualitative) FROM Operator Observation
Hardware workload/stress level versus Fleet representative workload/stress level (Qualitative) FROM Operator Interview
Hardware workload/stress level versus Fleet representative workload/stress level (Qualitative) FROM OTD Observation
Impact of non-representative workload on hardware reliability (Qualitative) FROM Operator Observation
Impact of non-representative workload on hardware reliability (Qualitative) FROM OTD Observation

Data Requirement
DT operating time (hh:mm:ss) FROM DT Report
DT operational mission failures (Number) FROM DT Report
DT demonstrated $MTBOMF_{HW}$ (hh:mm:ss) FROM DT Report
Hardware workload/stress level during DT versus Fleet representative workload/stress level (Qualitative) FROM DT Report
Impact of DT workload on hardware reliability (Qualitative) FROM DT Report
DT hardware failure modes and causes (Qualitative) FROM DT Report
Similar existing system $MTBOMF_{HW}$ (hh:mm:ss) FROM Fleet Maintenance Data

e. **Measure:** $MTBF_{HW}$ = total system operating time/ number of hardware failures.
Criterion: Ideally, a specified time.

Like MTBOMF, MBTF can be divided between HW and SW. Use the $MBTOMF_{HW}$ DRs.

f. **Measure:** Mean Time Between Operational Mission Software Fault ($MTBOMF_{SW}$) = total system operating time/number of operational mission software faults (OMF_{SW}).
Criterion: Ideally, a specified time.

Hardware and software have different reliability behaviors. Breaking reliability between HW and SW is required. $MTBOMF_{SW}$ should be a critical measure for reliability evaluations.

Data Requirement
Date/time start test (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time end test (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time system turned on (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time system turned off (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time system set to standby (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time system out of standby (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time fault occurs (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Software fault description and cause (Qualitative) FROM Maintainer Observation
Mission impact of fault (Qualitative) FROM Operator Observation
Mission impact of fault (Qualitative) FROM OTD Observation
Software workload/stress level versus Fleet representative workload/stress level (Qualitative) FROM Operator Interview
Software workload/stress level versus Fleet representative workload/stress level (Qualitative) FROM OTD Observation
Impact of non-representative workload on software reliability (Qualitative) FROM Operator Observation
Impact of non-representative workload on software reliability (Qualitative) FROM OTD Observation
DT operating time (hh:mm:ss) FROM DT Report
DT operational mission faults (Number) FROM DT Report
DT demonstrated $MTBOMF_{SW}$ (hh:mm:ss) FROM DT Report
Software workload/stress level during DT versus Fleet representative workload/stress level (Qualitative) FROM DT Report
System workload/stress level during DT (Qualitative) FROM DT Report
DT software fault descriptions and causes (Qualitative) FROM DT Report
Similar existing system $MTBOMF_{SW}$ (hh:mm:ss) FROM Fleet Maintenance Data

g. **Measure:** $MTBF_{SW}$ = total system operating time/ number of software faults.
Criterion: ideally, a specified time.

Use the $MBTOMF_{SW}$ DRs.

h. **Measure:** Mission Reliability (R) = number of missions without an OMF_{HW} or OMF_{SW}/ total number of missions.
Criterion: Ideally, a specified probability.

This is the binomial metric for system reliability. For an on-demand SUT, R is the typical critical measure. $MTBOMF_{SYS}$ may be used as a critical measure for on-demand systems, if that system has a defined standard mission length, allowing MTBOMF to be converted to an R value. R is not divided between HW and SW.

Data Requirement
Date/time start test (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time end test (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time mission start (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time mission end (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Status of system at mission completion/abort (Qualitative) FROM Operator Observation
Status of system at mission completion/abort (Qualitative) FROM OTD Observation
Hardware failure mode and cause (Qualitative) FROM Maintainer Observation
Software fault description and cause (Qualitative) FROM Maintainer Observation
Mission impact of failure/fault (Qualitative) FROM Operator Observation
Mission impact of failure/fault (Qualitative) FROM OTD Observation
System workload/stress level versus Fleet representative workload/stress level (Qualitative) FROM Operator Interview
System workload/stress level versus Fleet representative workload/stress level (Qualitative) FROM OTD Observation
Impact of non-representative workload on reliability (Qualitative) FROM Operator Observation
Impact of non-representative workload on reliability (Qualitative) FROM OTD Observation
DT number of missions without an operational mission failure/fault (Number) FROM DT Report
DT number of missions (Number) FROM DT Report
DT demonstrated R (Percentage) FROM DT Report
System workload/stress level during DT versus Fleet representative workload/stress level (Qualitative) FROM DT Report
Impact of DT workload on reliability (Qualitative) FROM DT Report
DT hardware failure modes and causes (Qualitative) FROM DT Report
DT software fault descriptions and causes (Qualitative) FROM DT Report
DT assessment of infant mortality effect on test results (Qualitative) FROM DT Report
Highly accelerated life testing results (Qualitative) FROM HALT Report
Component reliability data (Qualitative) FROM DT Report
Component reliability impacts (Qualitative) FROM DT Report
Similar existing system R (Percentage) FROM Fleet Maintenance Data

i. **Measure:** Mission Reliability, <Mission Area> (R_{MA}) = number of <mission area> missions without an OMF_{HW} or OMF_{SW}/ total number of <mission area> missions.
Criterion: Probability.

When writing R_{MA}, replace the "MA" subscript with the mission area abbreviation (AW, ASW, etc.). Adjust the R DRs for a single mission.

5. Reference the list of additional reliability measures and DRs.

Unlike #4 above, these measures will not apply to most SUTs. They are included as additional brainstorming help for programs, and to help develop DRs, when one of these measures is appropriate.

a. **Measure:** Compatibility enables reliability.
Criterion: Yes.

All the concerns previously addressed in the compatibility COI can affect reliability.

Data Requirement
Issues with cooling (Qualitative) FROM Operator Observation
Issues with electricity supply (Qualitative) FROM Operator Observation
Issues with vibration (Qualitative) FROM Operator Observation
Issues with temperature (Qualitative) FROM Operator Observation
Issues with humidity (Qualitative) FROM Operator Observation
Issues with EMI (Qualitative) FROM Operator Observation

Data Requirement
Issues with space/weight (Qualitative) FROM Operator Observation
Issues with sea state (Qualitative) FROM Operator Observation
Issues with weather (Qualitative) FROM Operator Observation
Issues with cooling (Qualitative) FROM DT Report
Issues with electricity supply (Qualitative) FROM DT Report
Issues with vibration (Qualitative) FROM DT Report
Issues with temperature (Qualitative) FROM DT Report
Issues with humidity (Qualitative) FROM DT Report
Issues with EMI (Qualitative) FROM DT Report
Issues with space/weight (Qualitative) FROM DT Report
Issues with sea state (Qualitative) FROM DT Report
Issues with weather (Qualitative) FROM DT Report

b. **Measure:** Mean Flight Hours Between Operational Mission Failure ($MFHBOMF_{SYS}$) = total flight hours/ number of OMF_{HW} and OMF_{SW}.
Criterion: Ideally, specified time.

The DRs for this measure are very similar to MTBOMF, yet focuses on flight hours, rather than operating time. Defining what qualifies as flight hours is vital, and should be done in IEF section 1. Similar to this measure, MTBUM can be rewritten for aircraft as MFHBUM.

c. **Measure:** Mean Time Between Unscheduled Maintenance (MTBUM) = total system operating time/ number of unscheduled maintenance actions.
Criterion: Time.

MTBUM is almost equivalent to MTBF, but not exactly. Unscheduled maintenance does not require a failure. The DRs will be similar.

d. **Measure:** MCR = number of missions successfully completed/ number of missions attempted.
Criterion: Ideally, a specified probability.

It is unclear how R and MCR differ. The DRs for MCR are the same as those for R.

e. **Measure:** Mission Without Failure (MWF) = number of missions without a hardware failure or software fault/total number of missions.
Criterion: Ideally, a specified probability.

MWF is equivalent to R, but includes all failures/faults.

Data Requirement
Date/time start test (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time end test (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time mission start (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time mission end (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Status of system at mission completion (Qualitative) FROM Operator Observation
Status of system at mission completion (Qualitative) FROM OTD Observation
Mission impact of failure/fault (Qualitative) FROM Operator Observation
Mission impact of failure/fault (Qualitative) FROM OTD Observation
Mission impact of hardware failure frequency (Qualitative) FROM Operator Observation
Mission impact of software fault frequency (Qualitative) FROM Operator Observation
System workload/stress level versus Fleet representative workload/stress level (Qualitative) FROM Operator Observation
System workload/stress level versus Fleet representative workload/stress level (Qualitative) FROM OTD Observation
Impact of non-representative workload on reliability (Qualitative) FROM Operator Observation
Impact of non-representative workload on reliability (Qualitative) FROM OTD Observation
DT number of missions without an operational mission failure/fault (Number) FROM DT Report
DT number of missions (Number) FROM DT Report

Data Requirement
DT demonstrated MWF (Percentage) FROM DT Report
System workload/stress level during DT versus Fleet representative workload/stress level (Qualitative) FROM DT Report
Impact of DT workload on reliability (Qualitative) FROM DT Report
DT hardware failure modes and causes (Qualitative) FROM DT Report
DT software fault descriptions and causes (Qualitative) FROM DT Report
Similar existing system MWF (Percentage) FROM Fleet Mission Data

APPENDIX B - Maintainability Measures and Data Requirements

Purpose: Expand on the detail, already provided on Maintainability in the IEF checklist. The suggested measures and DRs provided below are optional, although a critical measure, with respect to OMFs, must be used. They are only provided to start the core team's brainstorming effort on how to best approach measures and DRs for Maintainability.

1. Ensure the full scope of SUT Maintainability is considered in the MBTD.

> ***Maintainability usually has two subtasks: "Perform Preventive Maintenance" and "Diagnose and Repair," yet can also have none. Further expansion of maintainability subtasks is encouraged for systems with a more detailed maintenance concept. The subtask breakdown (if used) must cover the full scope of maintenance.***
>
> ***Measures must cover all O-Level maintenance. Data collected must examine the full scope of maintainability. I-Level and D-Level maintenance typically fit in logistics.***
>
> ***Real-world maintainability data can be collected in a stand-alone "maintenance action" vignette. M-DEMO data is organized into a separate M-DEMO vignette.***

2. Verify the Maintainability data to be collected will support examination of Availability.

> ***Maintainability is the first part of the downtime component of availability. It addresses the ability to restore the system to fully operable, through corrective actions maintenance, and the ability to keep the system operable through preventive maintenance.***

3. Reference the list of suggested Maintainability measures and DRs.

> ***Measures and DRs, commonly used to address maintainability, are provided below. They should be considered for use on all testing efforts. Programs are not required to include all the measures and DRs below, as not all of them will apply to every system. Conversely, these measures and DRs may not cover the full scope of data, needed to be gathered for every system. Details on many of the measures below can be found in the 2020 OTA MOT&E MOA.***
>
> ***DRs with no highlighting should almost always be used with the associated measure. DRs highlighted blue are less commonly used. DRs highlighted gray will probably only apply in unique cases.***

a. **Measure:** Mean Corrective Maintenance Time for Operational Mission Failure, Hardware ($MCMTOMF_{HW}$) = total elapsed time to correct OMF_{HW}/ total number of OMF_{HW}.
Criterion: ideally, a specified time.

> ***Even if the system is not continuous, repair actions are continuous. MCMTOMF applies. Hardware and Software maintenance are very different. Separate MCMTOMF into HW and SW. A composite MCMTOMF could be calculated if the frequency of HW and SW OMFs are known. HW MCMT data can be gathered from M-DEMO, but may differ from real-world times (hence, those M-DEMO DRs).***

Data Requirement
Date/time hardware failure occurs (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time start troubleshooting (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Troubleshooting actions (Qualitative) FROM Maintainer Observation
Troubleshooting actions (Qualitative) FROM OTD Observation
Date/time hardware failure identified (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Hardware failure mode and cause (Qualitative) FROM Maintainer Observation
Date/time logistics need identified (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time logistics request submitted to onboard supply (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time off-board logistics request submitted by onboard supply (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time off-board logistics item received by onboard supply (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source

Data Requirement
Date/time item distributed to division for use (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Preparatory actions (Qualitative) FROM Maintainer Observation
Preparatory actions (Qualitative) FROM OTD Observation
Date/time start corrective maintenance (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Maintenance actions (Qualitative) FROM Maintainer Observation
Maintenance actions (Qualitative) FROM OTD Observation
Date/time end corrective maintenance (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Re-test actions (Qualitative) FROM Maintainer Observation
Re-test actions (Qualitative) FROM OTD Observation
Date/time system restored (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time corrective maintenance paused (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time corrective maintenance resumed (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Reason corrective maintenance paused (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
hardware maintainability usability assessment (SUS) FROM Maintainer Survey (S-x)
Issues with hardware maintainability (Qualitative) FROM OTD Observation
Issues with hardware maintainability (Qualitative) FROM Maintainer Observation
Issues with hardware maintenance regarding tools (Qualitative) FROM Maintainer Observation
Issues with hardware maintenance regarding documentation (Qualitative) FROM Maintainer Observation
Issues with hardware maintenance regarding onboard supply (Qualitative) FROM Maintainer Observation
Issues with hardware maintenance regarding accessibility (Qualitative) FROM Maintainer Observation
Issues with hardware maintenance regarding new or special skills (Qualitative) FROM Maintainer Observation
Issues with hardware maintenance regarding manning/workload (Qualitative) FROM Maintainer Observation
Issues with hardware maintenance regarding built-in test (Qualitative) FROM Maintainer Observation
Issues with hardware maintenance regarding safety (Qualitative) FROM Maintainer Observation
M-DEMO comparison to expected Fleet hardware maintenance (Qualitative) FROM Maintainer Observation
M-DEMO comparison to expected Fleet hardware maintenance (Qualitative) FROM OTD Observation
DT corrective maintenance time for hardware operational mission failures (hh:mm:ss) FROM DT Report
DT hardware operational mission failures (Number) FROM DT Report
DT demonstrated $MCMTOMF_{HW}$ (hh:mm:ss) FROM DT Report
DT hardware failure modes and causes (Qualitative) FROM DT Report
DT evaluation of common failure modes and fix times (Qualitative) FROM DT Report
DT Test Incident Report (Qualitative) FROM DT Trouble Report
Similar existing system $MCMTOMF_{HW}$ (hh:mm:ss) FROM Fleet Maintenance Data

b. **Measure:** Mean Time to Repair, Hardware ($MTTR_{HW}$) = total elapsed time to correct hardware failures/ total number of hardware failures.
Criterion: Time.

Repair of all failures (not just OMFs) is relevant to maintainability. The DRs for MTTR are the same as those for MCMTOMF. Analysis of both measures is done after OMFs are scored.

c. **Measure:** Mean Corrective Maintenance Time for Operational Mission Faults, Software ($MCMTOMF_{SW}$) = total elapsed time to restore software-intensive systems after OMF_{SW}/ total number of OMF_{SW}.
Criterion: Ideally, a specified time.

Data Requirement
Date/time software fault occurs (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time start troubleshooting (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Troubleshooting actions (Qualitative) FROM Maintainer Observation
Troubleshooting actions (Qualitative) FROM OTD Observation
Date/time software fault isolated (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Software fault description and cause (Qualitative) FROM Maintainer Observation
Date/time logistics need identified (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time logistics request submitted to onboard supply (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time off-board logistics request submitted by onboard supply (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source

Data Requirement
Date/time off-board logistics item received by onboard supply (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time item distributed to division for use (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Preparatory actions (Qualitative) FROM Maintainer Observation
Preparatory actions (Qualitative) FROM OTD Observation
Date/time start corrective maintenance (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Maintenance actions (Qualitative) FROM Maintainer Observation
Maintenance actions (Qualitative) FROM OTD Observation
Date/time end corrective maintenance (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Re-test actions (Qualitative) FROM Maintainer Observation
Re-test actions (Qualitative) FROM OTD Observation
Date/time all processes, functions, files, and databases restored to a tactically useful state (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time corrective maintenance paused (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time corrective maintenance resumed (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Reason corrective maintenance paused (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Software maintainability usability assessment (SUS) FROM Operator Survey (S-x)
Software maintainability usability assessment (SUS) FROM System Administrator Survey (S-y)
Impact of system usability on software maintenance (Qualitative) FROM Operator Observation
Impact of system usability on software maintenance (Qualitative) FROM System Administrator Observation
Issues with software maintainability (Qualitative) FROM OTD Observation
Issues with software maintainability (Qualitative) FROM System Administrator Observation
Issues with software maintenance regarding tools (Qualitative) FROM System Administrator Observation
Issues with software maintenance regarding documentation (Qualitative) FROM System Administrator Observation
Issues with software maintenance regarding onboard supply (Qualitative) FROM System Administrator Observation
Issues with software maintenance regarding accessibility (Qualitative) FROM System Administrator Observation
Issues with software maintenance regarding new or special skills (Qualitative) FROM System Administrator Observation
Issues with software maintenance regarding manning/workload (Qualitative) FROM System Administrator Observation
Issues with software maintenance regarding built-in test (Qualitative) FROM System Administrator Observation
Issues with software maintenance regarding safety (Qualitative) FROM System Administrator Observation
M-DEMO comparison to expected Fleet software maintenance (Qualitative) FROM Maintainer Observation
M-DEMO comparison to expected Fleet software maintenance (Qualitative) FROM OTD Observation
DT corrective maintenance time for software operational mission faults (hh:mm:ss) FROM DT Report
DT software operational mission faults (Number) FROM DT Report
DT demonstrated $MCMTOMF_{SW}$ (hh:mm:ss) FROM DT Report
DT software fault descriptions and causes (Qualitative) FROM DT Report
DT evaluation of common fault descriptions and fix times (Qualitative) FROM DT Report
DT Test Incident Report (Qualitative) FROM DT Trouble Report
Similar existing system $MCMTOMF_{SW}$ (hh:mm:ss) FROM Fleet Maintenance Data

d. **Measure:** Mean Time to Repair, Software ($MTTR_{SW}$) = total elapsed time to restore from software faults/ total number of software faults.
Criterion: Time.

Repair of all faults (not just OMFs) is relevant to maintainability. The DRs for MTTR are the same as those for MCMTOMF. Analysis of both measures is done after OMFs are scored.

4. Reference the list of <u>additional</u> maintainability measures and DRs.

Unlike #3 above, these measures are less likely to apply. They are included as additional brainstorming help for programs, and to help develop DRs, when one of these measures is appropriate.

a. **Measure:** Mean Preventive Maintenance Time (MPMT) = total elapsed time to complete PMS/ total number of PMS actions.
Criterion: Time.

PMS time can be a significant part of downtime. This measure is the vehicle for collecting preventive maintenance data.

Data Requirement
Date/time system taken down for preventive/planned maintenance (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time system restored (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Preventive/planned maintenance type and periodicity (Nominal) FROM Maintainer Observation
Anomalies or delays encountered during preventive/planned maintenance (Qualitative) FROM Maintainer Observation
Issues with preventive maintenance (Qualitative) FROM OTD Observation
Issues with preventive maintenance (Qualitative) FROM Maintainer Observation
Issues with preventive maintenance regarding tools (Qualitative) FROM Maintainer Observation
Issues with preventive maintenance regarding documentation (Qualitative) FROM Maintainer Observation
Issues with preventive maintenance regarding onboard supply (Qualitative) FROM Maintainer Observation
Issues with preventive maintenance regarding accessibility (Qualitative) FROM Maintainer Observation
Issues with preventive maintenance regarding new or special skills (Qualitative) FROM Maintainer Observation
Issues with preventive maintenance regarding manning/workload (Qualitative) FROM Maintainer Observation
Issues with preventive maintenance regarding built-in test (Qualitative) FROM Maintainer Observation
Issues with preventive maintenance regarding safety (Qualitative) FROM Maintainer Observation
DT preventive maintenance time (hh:mm:ss) FROM DT Report
DT preventive maintenance actions (Number) FROM DT Report
DT demonstrated MPMT (hh:mm:ss) FROM DT Report
DT preventive/planned maintenance type and periodicity (Qualitative) FROM DT Report
Preventive/planned maintenance deferred during test (Nominal) FROM Maintainer Observation
Preventive/planned maintenance deferred beyond allowable tolerances (Nominal) FROM Maintainer Observation
Similar existing system MPMT (hh:mm:ss) FROM Fleet Maintenance Data

b. **Measure:** Maintainer training prepares personnel to maintain the system.
Criterion: Yes.

Data Requirement
OTD assessment of accessibility of maintainer training (Qualitative) FROM OTD Observation
OTD assessment of frequency of maintainer training (Qualitative) FROM OTD Observation
OTD assessment of completeness of maintainer training (Qualitative) FROM OTD Observation
OTD assessment of accuracy of maintainer training (Qualitative) FROM OTD Observation
OTD assessment of maintainer training method (Qualitative) FROM OTD Observation
Maintainer opinion of accessibility of maintainer training FROM Maintainer Interview
Maintainer opinion of frequency of maintainer training FROM Maintainer Interview
Maintainer opinion of completeness of maintainer training FROM Maintainer Interview
Maintainer opinion of utility of maintainer training FROM Maintainer Interview

c. **Measure:** Maximum Corrective Maintenance Time for OMFs (MaxCMTOMF).
Criterion: Time.

Normally calculated at 90th percentile. The DRs are the same as MCMTOMF. The DT data would need to be provided for each separate corrective maintenance action to understand the distribution.

d. **Measure:** Maximum Corrective Maintenance Time (MaxCMT).
Criterion: Time.

Equivalent to above, but for all corrective maintenance action.

e. **Measure:** MRT = total elapsed time to reboot a software-intensive system/ total number of software reboots.
Criterion: Time.

Data Requirement
Date/time start software reboot (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time end software reboot (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Software fault description and cause (Qualitative) FROM Maintainer Observation
Reboot type (Nominal) FROM Maintainer Observation
Reboot type (Nominal) FROM OTD Observation

f. **Measure:** Mean Cold Reboot Time (MRT_C) = total elapsed time to cold-start a software-intensive system/total number of cold-start reboots.
Criterion: Time.

DRs for this measure are the same as those for MRT.

g. **Measure:** Mean Warm Reboot Time (MRT_W) = total elapsed time to warm-start a software-intensive system/total number of warm-start reboots.
Criterion: Time.

DRs for this measure are the same as those for MRT.

h. **Measure:** Probability of BIT Correct Fault Detection (P_{CFD}) = number of failures/faults correctly detected by BIT/ number of actual system failures/faults.
Criterion: Probability.

Data Requirement
Date/time hardware failure occurs (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time software fault occurs (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Hardware failure mode and cause (Qualitative) FROM Maintainer Observation
Software fault description and cause (Qualitative) FROM Maintainer Observation
BIT indications at time of hardware failure (Qualitative) FROM Maintainer Observation
BIT indications at time of software fault (Qualitative) FROM Maintainer Observation
Assessment of BIT usability (SUS) FROM Maintainer Survey (S-x)
Issues with hardware maintenance regarding built-in test (Qualitative) FROM Maintainer Observation
Issues with software maintenance regarding built-in test (Qualitative) FROM Maintainer Observation
DT number of failures/faults correctly detected by BIT (Number) FROM DT Report
DT number of failures/faults (Number) FROM DT Report
DT demonstrated P_{CFD} (Percentage) FROM DT Report
DT evaluation of BIT strengths and shortcomings (Qualitative) FROM DT Report
DT hardware failure modes and causes (Qualitative) FROM DT Report
DT software fault descriptions and causes (Qualitative) FROM DT Report

i. **Measure:** Probability of BIT Correct Failure/Fault Isolation (P_{CFI}) to a specified replaceable assembly = number of failures/faults correctly isolated/ total number of failures/faults correctly detected by BIT.
Criterion: Probability.

Data Requirement
Date/time of BIT failure/fault detection (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
BIT indications at time of failure/fault (Qualitative) FROM Maintainer Observation
Indicated failed/faulted component (Qualitative) FROM BIT Readout
Actual failed/faulted component (Qualitative) FROM Maintainer Observation
DT number of failures/faults correctly isolated by BIT (Number) FROM DT Report
DT number of BIT failure/fault isolations (Number) FROM DT Report
DT demonstrated P_{CFI} (Percentage) FROM DT Report

j. **Measure:** Probability of BIT False Alarm (P_{BFA}) = number of incorrect BIT failure/fault indications/ total number of BIT failure/fault indications.
Criterion: Probability.

Data Requirement
Date/time of BIT failure/fault detection (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
System status at time of BIT detection (Qualitative) FROM Maintainer Observation
BIT indications at time of failure/fault (Qualitative) FROM Maintainer Observation
Hardware failure mode and cause (Qualitative) FROM Maintainer Observation
Software fault description and cause (Qualitative) FROM Maintainer Observation
DT number of failures/faults correctly detected by BIT (Number) FROM DT Report
DT number of BIT failure/fault detections (Number) FROM DT Report
DT demonstrated P_{BFA} (Percentage) FROM DT Report
DT evaluation of BIT false alarms (Qualitative) FROM DT Report

k. **Measure:** False BIT Indications per System Operating Hour (BFAh) = number of incorrect BIT failure/fault indications/ total number of operating hours.
Criterion: Rate.

Total system operating time is collected through DRs associated with other measures.

Data Requirement
Date/time of BIT failure/fault detection (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
System status at time of BIT detection (Qualitative) FROM Maintainer Observation
BIT indications at time of failure/fault (Qualitative) FROM Maintainer Observation
Hardware failure mode and cause (Qualitative) FROM Maintainer Observation
Software fault description and cause (Qualitative) FROM Maintainer Observation
DT number of failures/faults correctly detected by BIT (Number) FROM DT Report
DT number of BIT failure/fault detections (Number) FROM DT Report
DT demonstrated BFAh (Number/hr) FROM DT Report
DT evaluation of BIT false alarms (Qualitative) FROM DT Report

l. **Measure:** MTBBFA = Total system operating time/ number of incorrect BIT failure/fault indications.
Criterion: Time.

Total SOT is collected through DRs associated with other measures.

Data Requirement
Date/time of BIT failure/fault detection (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
System status at time of BIT detection (Qualitative) FROM Maintainer Observation
BIT indications at time of failure/fault (Qualitative) FROM Maintainer Observation
Hardware failure mode and cause (Qualitative) FROM Maintainer Observation
Software fault description and cause (Qualitative) FROM Maintainer Observation
DT number of failures/faults correctly detected by BIT (Number) FROM DT Report
DT number of BIT failure/fault detections (Number) FROM DT Report
DT demonstrated MTBBFA (hh:mm:ss) FROM DT Report
DT evaluation of BIT false alarms (Qualitative) FROM DT Report

APPENDIX C - Logistic Supportability Measures and Data Requirements

Purpose: Expand on the detail already provided on logistic supportability in the IEF checklist. The suggested measures and DRs provided below are optional, although a critical measure, with respect to OMFs, must be used. They are only provided to start the core team's brainstorming effort on how to best approach measures and DRs for logistic supportability.

1. Ensure the full scope of SUT logistics supportability is considered in the MBTD.

Logistic Supportability often has no subtasks (simple systems), but can also have many (large platforms). The subtask breakdown (if used) must cover the full scope of logistics.

Measures must cover onboard and off-board logistics, as well as provisioning status. Initial provisioning and interim sparing impact availability, as well as down-stream sustainment efforts and associated costs. Data collected must closely examine these details of logistics.

Logistics actions supporting maintenance best apply to the maintenance vignettes. Larger logistics actions like storage loads probably require their own vignette.

2. Verify the logistics data to be collected will support examination of Availability.

Administrative and logistics delay time is the second part of the downtime component of availability.

3. Reference the list of suggested logistic supportability measures and DRs.

Measures and DRs commonly used to address logistic supportability are provided below. They should be considered for use on all testing efforts. Programs are not required to include all the measures and DRs below, as not all of them will apply to every system. Conversely, these measures and DRs may not cover the full scope of data needed to be gathered for every system. Life Cycle Sustainment Plan (LCSP) and Mean Logistics Delay Time for Operational Mission Failures (MLDTOMF) are recommended as critical. Details on many of the measures below can be found in chapter 4 of this Handbook and the 2020 OTA MOT&E MOA.

DRs with no highlighting should almost always be used with the associated measure. DRs highlighted blue are less commonly used. DRs highlighted gray will probably only apply in unique cases.

a. **Measure:** LCSP adequate, funded, and implemented.
Criterion: Yes.

This measure is relevant to every phase of OT. The DRs provided below are focused on IOT&E and FOT&E. APML and IWST assistance is vital.

Data Requirement
LCSP signature date or anticipated signature date (dd-mmm-yy) FROM Program Office Correspondence
MSD for current increment (dd-mmm-yy) FROM Program Office Correspondence
Plan to achieve MSD is feasible (Qualitative) FROM APML Correspondence
Plan to achieve MSD is feasible (Qualitative) FROM IWST Correspondence
Independent Logistic Assessment (ILA) date (dd-mmm-yy) FROM Program Office Correspondence
Problems and issues with logistic support (Qualitative) FROM Maintainer Observation
Problems and issues with logistic support (Qualitative) FROM ILA Report
Problems and issues with logistic support (Qualitative) FROM ILA Appendix to LCSP
SPB signature date or anticipated signature date (dd-mmm-yy) FROM Program Office Correspondence
SPB-identified sustainment issues affecting availability (Various) FROM Program Office Correspondence
Onboard parts supplies distributed to force (Qualitative) FROM Program Office Correspondence
Interim spares in place at wholesale (Qualitative) FROM Program Office Correspondence
Incorrect or missing stock numbers in NALCOMIS and/or RSUPPLY (Various) FROM OTD Review
IMEC list (Various) FROM APML Correspondence
Differences between IMEC list and Mission Critical Subsystem Matrix (Various) FROM OTD Review

Data Requirement
Critical components not in the COSAL/AVCAL (Various) FROM OTD Review
Support activities such as help desk in place (Qualitative) FROM Program Office Correspondence
Unique testing/calibration equipment available (Qualitative) FROM Program Office Correspondence
Facilities, infrastructure, and support equipment identified and ready to support (Qualitative) FROM Program Office Correspondence
Configuration management established (Qualitative) FROM Program Office Correspondence
Parts buy-out funding in place (Qualitative) FROM Program Office Correspondence
Funding for PPBE budgeted (Qualitative) FROM Program Office Correspondence
Design drawings and data rights support parts affordability/availability (Qualitative) FROM Chief Engineer Correspondence
Design drawings and data rights support parts affordability/availability (Qualitative) FROM APML Correspondence
Design drawings and data rights support parts affordability/availability (Qualitative) FROM IWST Correspondence
Adequacy of O-to-D-level maintenance concept to support availability (Qualitative) FROM APML Correspondence
Readiness of O-to-D-level maintenance concept to support availability (Qualitative) FROM IWST Correspondence
Supply risk mitigation provided by parts commonality with existing systems (Qualitative) FROM APML Correspondence
Supply risk mitigation provided by parts commonality with existing systems (Qualitative) FROM IWST Correspondence
Procurement strategies and sustainment costs are acceptable (Qualitative) FROM APML Correspondence
Procurement strategies and sustainment costs are acceptable (Qualitative) FROM IWST Correspondence
RSSP and associated funding are acceptable (Various) FROM APML Correspondence
RSSP and associated funding are acceptable (Various) FROM IWST Correspondence

b. **Measure:** MLDTOMF = total off-board logistics delay time related to OMFs / number of OMFs requiring off-board logistic support.
Criterion: ideally, a specified time.

MLDTOMF is almost always a critical measure for this COI. Even if the system is not continuous, the supply system is continuous. MLDTOMF applies to every SUT with off-board supply. If this measure has a specified threshold in the capabilities document, verify the equation above matches the requirement. For example, the specified denominator may include all repairs. Adjust measures and criterion accordingly. Make the same verification for MLDT.

Context matters. If the part was (was not) expected to be in Onboard Repair Parts (OBRP), but it was not (was) held, MLDT results get an asterisk (e.g., the PM brings an extra "bag of part" to test). Item Acquisition Advice Code (AAC) tells us whether it is supposed to be stocked, procured on-demand, or obsolete, which could impact MLDT. Anomalies like the host ship needing to return to port to receive the part impacts MLDT. Off-board supply paths that do not represent those used by the fleet after MSD may yield questionable times. With limited LDT samples, the results can misrepresent operational realities. Context behind the data mitigates this risk.

Data Requirement
Anticipated source of part (Qualitative) FROM Supply Personnel Observation
Date/time failure/fault occurs (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Hardware failure mode and cause (Qualitative) FROM Maintainer Observation
Software fault description and cause (Qualitative) FROM Maintainer Observation
Stock number of item needed per tech manual (NSN/NIIN) FROM Technical Manual
Stock number of item requested from parts list (NSN/NIIN) FROM NALCOMIS and/or RSUPPLY
Item AAC (Qualitative) FROM NALCOMIS and/or RSUPPLY
Date/time off-board logistics item received by onboard supply (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Anomalies in delivery affecting logistics delay time (Qualitative) FROM Supply Personnel Observation
Aspects of delivery affecting operational realism of logistics delay time (Qualitative) FROM Supply Personnel Observation
Description of item received (Qualitative) FROM Supply Personnel Observation
Stock number of item received (NSN/NIIN) FROM Supply Personnel Observation
Anomalies in supply chain affecting logistics delay time (Qualitative) FROM Supply Department Interview

c. **Measure:** MLDT = total off-board logistics delay time / number of off-board logistics requests.

Criterion: usually 'No threshold", but ideally, there is a specified time threshold.

The DRs for MLDT are the same as those for MLDTOMF. The data collected for other measures allows scoring of failures/faults as OMFs, which allows analysis of both measures.

d. **Measure:** Percent provisioning complete = number of unique stock numbers assigned NSNs / total number of unique replaceable parts.
Criterion: No threshold (percent).

This measure assesses the initial stage (completed by the program office) and/or interim stage (completed by the support contractor and leveraging existing program supplies). The APML/PSM should know the status. As such, this measure is likely DT Only.

Data Requirement
List of all replaceable parts by stock number (Various) FROM System NALCOMIS or RSUPPLY Data
List of all parts with assigned NSN/NIIN (Various) FROM APML Correspondence
Factors impacting provisioning of parts (Various) FROM APML Correspondence
List of all parts with identified ISEA (Various) FROM APML Correspondence
DMSMS risk assessment (Qualitative) FROM APML Correspondence
MSD for current increment (dd-mmm-yy) FROM Program Office Correspondence
Date provisioning status examined (dd-mmm-yy) FROM OTD Observation
Expected provisioning date of each part (Various) FROM APML Correspondence
Plan to mitigate provisioning risks (Various) FROM APML Correspondence
IMEC list (Various) FROM APML Correspondence
DT assessment of provisioning status (Qualitative) FROM DT Report

e. **Measure**: Interim support contract duration.
Criterion: No threshold (months).

The impact of logistics on availability depends on how often logistics must support system restoration to operation. This measure covers corrective and preventative maintenance actions. This measure assesses the adequacy of plans for the second (interim support) stage of provisioning replacement parts.

Data Requirement
Status of interim support contract (dd-mmm-yy) FROM Program Office Correspondence
Planned interim support contract award date (dd-mmm-yy) FROM Program Office Correspondence
MSD for current increment (dd-mmm-yy) FROM Program Office Correspondence
Pre-MSD inspection date (dd-mmm-yy) FROM Program Office Correspondence
Adequacy of interim support contracts (Various) FROM APML Correspondence
Adequacy of interim support contracts (Various) FROM IWST Correspondence
Current on-shelf quantity of each part (Various) FROM APML Correspondence
Date provisioning status examined (dd-mmm-yy) FROM OTD Observation
Provisioning rate of each part for initial spares (Various) FROM APML Correspondence
Parts not bought-out (Various) FROM FRWQ
Planned use rates for each part in production (Various) FROM APML Correspondence
Planned use rates for each part in repairs (Various) FROM APML Correspondence
Interim contract expected production rate of each part (Various) FROM Interim Sparing Contract
Adequacy of sparing plan versus need (Various) FROM APML Correspondence
Adequacy of sparing plan versus need (Various) FROM IWST Correspondence

f. **Measure:** Percent of stock numbers on-hand in wholesale = number of stock numbers expected in wholesale for which one or more single unit is held / total number of stock numbers expected to be in wholesale.
Criterion: No threshold (percent).

The impact of offboard logistics on availability depends on how often offboard parts requests, technical support, or I/D-Level repair must support system restoration to operation. This measure primarily assesses the third (NAVSUP support) stage of provisioning replacement parts, which begins after MSD. However, it can be used in the first two stages as long as the denominator is correctly scaled to the current supply expectations, and the numerator only examines stock numbers counted in the denominator.

Data Requirement
List of all replaceable parts by stock number expected in wholesale (Various) FROM System NALCOMIS or RSUPPLY Data
List of all parts on-hand in wholesale (Various) FROM One Touch Support Depot Inventory
Factors impacting wholesale supplies (Various) FROM APML Correspondence
MSD for current increment (dd-mmm-yy) FROM Program Office Correspondence
Date wholesale parts inventory examined (dd-mmm-yy) FROM OTD Observation
Plan to mitigate wholesale supply risks (Various) FROM APML Correspondence
IMEC list (Various) FROM APML Correspondence
DT assessment of depot supply status (Qualitative) FROM DT Report

g. **Measure:** Percent of NSNs/NIINs ready for MSD = number of NSNs/NIINs deemed ready for MSD / total number of NSNs/NIINs required at MSD.
Criterion: No threshold (percent).

This measure examines parts depth qualitatively, giving an up-or-down result for each part. The first DR below is the measure denominator. The second DR is the measure numerator.

Data Requirement
List of all replaceable parts by stock number (Various) FROM System NALCOMIS or RSUPPLY Data
List of all parts ready for MSD (Various) FROM IWST Correspondence
MSD for current increment (dd-mmm-yy) FROM Program Office Correspondence
Date parts MSD readiness examined (dd-mmm-yy) FROM OTD Observation
Plan to mitigate MSD readiness risks (Various) FROM APML Correspondence
Problems and issues with parts use rates (Qualitative) FROM IWST Correspondence
IMEC list (Various) FROM APML Correspondence
DT assessment of NIINs readiness for MSD (Qualitative) FROM DT Report

h. **Measure:** Tools and publications are on-hand.
Criterion: Yes.

Deterministic measure. All of the necessary items are there, or are not.

Data Requirement
Maintenance procedures/manuals on-hand at test (Qualitative) FROM OTD Observation
Maintenance procedures/manuals expected to be on-hand (Qualitative) FROM Maintainer Observation
Maintenance procedures/manuals required onboard (Qualitative) FROM Program Office Correspondence
Technical manuals and/or IETM on-hand at test (Qualitative) FROM OTD Observation
Technical manuals and/or IETM expected to be on-hand (Qualitative) FROM Maintainer Observation
Technical manuals and/or IETM required onboard (Qualitative) FROM Program Office Correspondence
Operating procedures/manuals on-hand at test (Qualitative) FROM OTD Observation
Operating procedures/manuals expected to be on-hand (Qualitative) FROM Operator Observation
Operating procedures/manuals required onboard (Qualitative) FROM Program Office Correspondence
System-specific tools on-hand at test (Qualitative) FROM OTD Observation
System-specific tools expected to be on-hand (Qualitative) FROM Operator Observation
System-specific tool required onboard (Qualitative) FROM Program Office Correspondence

4. Reference the list of optional additional (non-critical) logistic supportability measures and DRs.

Unlike the measure above, these measures are less likely to apply. They are included as additional brainstorming help for programs, and to help develop DRs, when one of these measures is appropriate. These measures are expected to be non-critical.

a. **Measure:** Percent of out-of-stock inventory for onboard parts/supplies.
Criterion: No threshold (percent).

Data is gathered for individual parts/consumables. Reporting as a single percentage is possible, though item-by-item may be more meaningful.

Data Requirement
Number of onboard inventory items (Number) FROM Supply Inspection
Number of expected onboard inventory items (Number) FROM Supply Inspection
Number of required onboard inventory items (Number) FROM Ship's COSAL
Number of expected OBRP=0 inventory items (Number) FROM Supply Inspection
Missing items description and quantity (Various) FROM Supply Inspection
Outstanding allowance replenishment docs executed prior to inspection (Various) FROM NALCOMIS and/or RSUPPLY
Status of procurement actions on outstanding allowance replenishment docs executed prior to inspection (Various) FROM IWST Correspondence
Cause for item absence, if known (Qualitative) FROM Supply Observation
Program-wide net effectiveness (Various) FROM IWST One Touch Support Analysis
Program-wide gross effectiveness (Various) FROM IWST One Touch Support Analysis

b. **Measure:** Percent of hardware maintenance requiring immediate use of parts.
Criterion: No threshold (percent).

Measure is calculated based on encountered repair actions, not all possible repair actions.

Data Requirement
Date/time start corrective maintenance (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Hardware failure mode and cause (Qualitative) FROM Maintainer Observation
Date/time start preventive maintenance (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Preventative/planned maintenance type and periodicity (Nominal) FROM Maintainer Observation
Date/time part installed (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Number of maintenance actions requiring parts (Number) FROM Maintenance Logs
Number of past hardware maintenance actions (Number) FROM Maintenance Logs
Number of MRCs requiring parts (Number) FROM OTD Review
DT number of maintenance actions requiring parts (Number) FROM DT Report
DT number of hardware maintenance actions (Number) FROM DT Report

c. **Measure:** Percent of maintenance actions requiring off-board supply and/or support.
Criterion: No threshold (percent).

Measure is calculated based on encountered repair actions, not all possible repair actions.

Data Requirement
Date/time start corrective maintenance (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time off-board logistics item received by onboard supply (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Number of past repair actions requiring off-board support (Number) FROM Maintenance Logs
Number of past repair actions (Number) FROM Maintenance Logs
Description of off-board support (Qualitative) FROM Maintenance Logs

Data Requirement
Program-wide impact of allowancing on percentage of repairs requiring off-board supply (Various) FROM IWST One Touch Support Analysis
Recommended OBRP allowancing changes (Various) FROM IWST One Touch Support Analysis
DT number of repair actions requiring off-board support (Number) FROM DT Report
DT number of repair actions (Number) FROM DT Report

d. **Measure:** The technical support desk aids in system maintenance.
Criterion: Yes.

Qualitative measure. Help desk use is likely witnessed more in support of maintenance.

Data Requirement
Date/time help desk call placed (dd-mmm-yy hh:mm:ss) FROM Time Source
Date/time help desk message left (dd-mmm-yy hh:mm:ss) FROM Time Source
Date/time help desk call answered (dd-mmm-yy hh:mm:ss) FROM Time Source
Date/time help desk message returned (dd-mmm-yy hh:mm:ss) FROM Time Source
Date/time help desk call concluded (dd-mmm-yy hh:mm:ss) FROM Time Source
Hardware failure mode and cause (Qualitative) FROM Maintainer Observation
Software fault description and cause (Qualitative) FROM Maintainer Observation
Results of help desk call (Qualitative) FROM Maintainer Observation
Results of help desk call (Qualitative) FROM OTD Observation
Opinion of help desk support for maintenance (Qualitative) FROM Maintainer Interview (S-x)
Opinion of help desk support for maintenance (Likert Scale) FROM Maintainer Survey (S-x)
Issues with help desk support for maintenance (Qualitative) FROM Maintainer Observation
Issues with help desk availability (Qualitative) FROM Maintainer Observation
DT assessment of help desk support for maintenance (Qualitative) FROM DT Report

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APPENDIX D - Availability Measures and Data Requirements

Purpose: Expand on the detail already provided on Availability in the IEF checklist. The suggested measures and DRs provided below are optional, with the exception of A_O, or an appropriate variant. They are only provided to start the core team's brainstorming effort on how to best approach measures and DRs for Availability.

1. Classify the SUT as continuous, on-demand, impulse, or hybrid (contains continuous components and on-demand components).

> ***Selection of most suitability measures depends on the duty cycle of the evaluated system. Determination of duty cycle type is best addressed from the perspective of system availability. Definitions of these terms are provided in chapter 6 of the Analyst Handbook. Defining the system as continuous does not preclude the use of measures typically applied to an on-demand system, and vice-versa. Yet, it does inform selection of the critical measures.***

2. Ensure the full scope of SUT Availability is considered in the MBTD.

> ***Availability is the KPP. It is the primary suitability concern. The reliability, maintainability, and logistics supportability COIs investigate aspects of the SUT that ultimately contribute to availability. As a result, almost all of the DRs that apply to availability measures are repetitions of DRs applied to other suitability measures. Make sure the components of availability not usually looked for in RM&L (standby/off/neutral time, AOD, etc.) are covered.***

3. Consider the impact of Availability on the other suitability COIs.

> ***Selection of availability measures has a direct effect on the RM&L measures. The AO equation can be written/calculated using MTBOMF, MCMTOMF, and MLDT. Generally, when AO is used as a measure (even if it is not critical), MTBOMF, MCMTOMF, and MLDT must also be used.***

4. For complex systems with several missions, consider evaluating Availability by mission area.

> ***Effectiveness focuses on specific missions. Suitability can have the same focus by examining availability for each mission. This means contributing data must be tagged by mission area for analysis.***

5. Ensure all terms within Availability calculations are defined/understood.

> ***Understanding, when the system is up (operating, in standby, and off) and down, is vital. Neutral time is also important to availability.***

6. Reference the suggested list of measures and DRs.

> ***Measures and DRs, commonly used to address Availability, are provided below. They should be considered for use on all testing efforts. Programs are not required to include all the measures and DRs below, as not all of them will apply to every system. Conversely, these measures and DRs may not cover the full scope of data needed to be gathered for every system. Details on many of the measures below can be found in the 2020 OTA MOT&E MOA.***
>
> ***DRs with no highlighting should almost always be used with the associated measure. DRs highlighted blue are less commonly used. DRs highlighted gray will probably only apply in unique cases.***

a. **Measure:** A_O = uptime/ (uptime + downtime).
Criterion: Ideally, a specified probability.

> ***For a continuously operated SUT, A_O is the critical measure. FMC may be used in place of A_O for multi-mission systems.***

Data Requirement
Date/time start test (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time end test (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time system turned on (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time system turned off (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time system set to standby (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time system out of standby (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time failure/fault occurs (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time system taken down for preventive/planned maintenance (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time system restored (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Hardware failure mode and cause (Qualitative) FROM Maintainer Observation
Software fault description and cause (Qualitative) FROM Maintainer Observation
Preventive/planned maintenance type and periodicity (Nominal) FROM Maintainer Observation
Mission impact of failure/fault (Qualitative) FROM Operator Observation
Mission impact of failure/fault (Qualitative) FROM OTD Observation
Impact of redundancy on availability (Qualitative) FROM Operator Observation
Impact of training on availability (Qualitative) FROM Operator Observation
Impact of system usability on availability (Qualitative) FROM Operator Observation
Impact of system transport on availability (Qualitative) FROM Operator Observation
Impact of system reliability on availability (Qualitative) FROM Operator Observation
Impact of corrective maintenance on availability (Qualitative) FROM Operator Observation
Impact of preventive/planned maintenance on availability (Qualitative) FROM Operator Observation
Impact of onboard logistic support on availability (Qualitative) FROM Operator Observation
Impact of off-board logistic support on availability (Qualitative) FROM Operator Observation
Impact of availability on mission (Qualitative) FROM Operator Observation
Operational tempo comparison to expected wartime usage (Qualitative) FROM Operator Observation
Operational tempo comparison to expected wartime usage (Qualitative) FROM OTD Observation
DT uptime (hh:mm:ss) FROM DT Report
DT downtime (hh:mm:ss) FROM DT Report
DT demonstrated A_O (Percentage) FROM DT Report
Preventive/planned maintenance deferred during test (Nominal) FROM Maintainer Observation
Preventive/planned maintenance deferred beyond allowable tolerances (Nominal) FROM Maintainer Observation

b. **Measure:** MC_{MA} = time system up for mission area/ total mission area time.
Criterion: Ideally, a specified probability.

This measure applies to multi-mission systems. When writing MC_{MA} measures, replace the "MA" subscript with the mission area abbreviation (AW, ASW, etc.). Adjust the A_O DRs for a single mission area.

Data Requirement
Mission area (Nominal) FROM Mission Plan
Critical systems equipment supporting mission area (Nominal) FROM Mission Essential Subsystem Matrices
Date/time start mission (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time end mission (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time subsystem turned on (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time subsystem turned off (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time subsystem set to standby (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time subsystem out of standby (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time failure/fault occurs (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time subsystem taken down for preventive/planned maintenance (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time subsystem restored (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Hardware failure mode and cause (Qualitative) FROM Maintainer Observation
Software fault description and cause (Qualitative) FROM Maintainer Observation
Preventive/planned maintenance type and periodicity (Nominal) FROM Maintainer Observation
Subsystem(s) affected by failure/fault (Qualitative) FROM Operator Observation

Data Requirement
Subsystem(s) affected by failure/fault (Qualitative) FROM OTD Observation
Subsystem(s) affected by preventive maintenance (Qualitative) FROM Maintainer Observation
Mission impact of failure/fault (Qualitative) FROM Operator Observation
Mission impact of failure/fault (Qualitative) FROM OTD Observation
DT uptime by mission area (hh:mm:ss) FROM DT Report
DT downtime by mission area (hh:mm:ss) FROM DT Report
DT demonstrated MC_{MA} (Percentage) FROM DT Report
Preventive/planned maintenance deferred during test (Nominal) FROM Maintainer Observation
Preventive/planned maintenance deferred beyond allowable tolerances (Nominal) FROM Maintainer Observation

c. **Measure:** On-demand Availability (A_{OD}) = number of times system was available/ number of times system was required.
Criterion: Ideally, a specified probability.

For an on-demand SUT, A_{OD} is the critical measure.

Data Requirement
Date/time start test (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time end test (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Date/time system required (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Status of system when required (Qualitative) FROM Operator Observation
Status of system when required (Qualitative) FROM OTD Observation
Hardware failure mode and cause (Qualitative) FROM Maintainer Observation
Software fault description and cause (Qualitative) FROM Maintainer Observation
Preventive/planned maintenance type and periodicity (Nominal) FROM Operator Observation
Mission impact of failure/fault (Qualitative) FROM Operator Observation
Mission impact of failure/fault (Qualitative) FROM OTD Observation
Impact of redundancy on availability (Qualitative) FROM Operator Observation
Impact of training on availability (Qualitative) FROM Operator Observation
Impact of system usability on availability (Qualitative) FROM Operator Observation
Impact of system transport on availability (Qualitative) FROM Operator Observation
Impact of system reliability on availability (Qualitative) FROM Operator Observation
Impact of corrective maintenance on availability (Qualitative) FROM Operator Observation
Impact of preventive/planned maintenance on availability (Qualitative) FROM Operator Observation
Impact of onboard logistic support on availability (Qualitative) FROM Operator Observation
Impact of off-board logistic support on availability (Qualitative) FROM Operator Observation
Impact of availability on mission (Qualitative) FROM Operator Observation
DT number of times the system was available (Number) FROM DT Report
DT number of times the system was required (Number) FROM DT Report
DT demonstrated A_{OD} (Percentage) FROM DT Report
Preventive/planned maintenance deferred during test (Nominal) FROM Maintainer Observation
Preventive/planned maintenance deferred beyond allowable tolerances (Nominal) FROM Maintainer Observation

7. Reference the list of additional Availability measures and DRs.

Unlike #6 above, these measures are less likely to apply. They are included as additional brainstorming help for programs, and to help develop DRs, when one of these measures is appropriate.

a. **Measure:** FMC = time system up for all mission areas/ total time.
Criterion: Ideally, a specified probability.

FMC is used for multi-mission systems, and is equivalent to A_O. The DRs for these two measures are the same.

b. **Measure:** Partial Mission Capable (PMC) = time system up for at least one mission areas/total time.
Criterion: Ideally a specified probability.

PMC is used for multi-mission systems. The DRs are the same as those for MC_{MA}.

c. **Measure:** Material Availability (A_M) = number of operational end items (ready for tasking)/ total population of end items.
Criterion: Ideally, a specified probability.

A_M is only used in concert with A_O or A_{OD}. DRs are limited to those needed beyond those in A_O or A_{OD}.

Data Requirement
Planned total population of end items (Number) FROM LCSP
Planned delivery schedule (Qualitative) FROM LCSP
Projected delivery schedule (Qualitative) FROM OTD Observation
Planned operational tempo (Qualitative) FROM CONOPS
Projected operational tempo (Qualitative) FROM OTD Observation
Planned mission reliability (Percentage) FROM CONOPS
Projected mission reliability (Percentage) FROM OTD Observation
Planned maintenance periods and durations (Qualitative) FROM LCSP
Projected maintenance periods and durations (Qualitative) FROM OTD Observation
Planned logistics support (Qualitative) FROM LCSP
Projected logistics support (Qualitative) FROM OTD Observation
Planned survivability (Qualitative) FROM CONOPS
Projected survivability (Qualitative) FROM OTD Observation
DT demonstrated A_M (Quantitative) FROM DT Report

d. **Measure:** Storage Availability = number of devices checked satisfactory for use/ number of devices checked.
Criterion: Ideally, a specified probability.

Storage Availability is used in conjunction with A_{OD}. DRs are limited to those needed beyond those in A_{OD}.

Data Requirement
Date/time system removed from storage (dd-mmm-yy hh:mm:ss) FROM Synchronized Time Source
Status of system when removed from storage (Qualitative) FROM Operator Observation
Status of system when removed from storage (Qualitative) FROM OTD Observation
Hardware failure mode and cause (Qualitative) FROM Maintainer Observation
Software fault description and cause (Qualitative) FROM Maintainer Observation
DT number of times the system was functional upon removal from storage (Number) FROM DT Report
DT number of times the system was removed from storage (Number) FROM DT Report
DT demonstrated Storage Availability (Percentage) FROM DT Report

e. **Measure:** Projected Operational Availability (A_O^{PROJ}) = MTBOMF/ (MTBOMF + MCMTOMF + $MLDTOMF^{PROJ}$).
Criterion: Ideally, a specified probability.

A_O^{PROJ} is only used in concert with A_O. DRs are limited to those needed beyond those in A_O.

Data Requirement
Logistics support comparison to Fleet representative logistics (Qualitative) FROM Operator Observation
Logistics support comparison to Fleet representative logistics (Qualitative) FROM OTD Observation
Logistics support comparison to Fleet representative logistics (Qualitative) FROM OTD Observation
Similar existing system MLDT (hh:mm:ss) FROM Post-test Analysis
Differences between SUT and existing system (Qualitative) FROM OTD Observation

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APPENDIX E - Training Measures and Data Requirements

Purpose: Expand on the detail already provided on training in the IEF checklist. The suggested measures and DRs provided below are optional. They are only provided to start the core team's brainstorming effort on how to best approach measures and DRs for training.

1. Consider the need for a training COI.

> ***The training COI is used by programs with major training efforts such as a simulator or a new schoolhouse. When a training COI is used, all training MBTD items are linked solely to that COI. Without a COI, aspects of training are covered under the tasks and COIs for which training is critical.***

2. Ensure the full scope of SUT training is considered in MBTD.

> ***Subtasks may be needed within the training COI. A few potential options are "provide schoolhouse training," "qualify personnel." and "maintain proficiency." These three subtasks could even be written as second level subtasks under the first level subtasks of "train operators" and "train maintainers".***
>
> ***Training vignettes may be required if specific test events will be completed to gather training data. Observing training at a schoolhouse is a good example.***
>
> ***With or without a COI, data must be gathered to examine the adequacy of training. Measures must cover both operations and maintenance, if applicable. Data collected must examine the full scope of training for the system.***
>
> ***Ultimately, successful mission completion and system maintenance prove that operators/maintainers emerging from the training pipeline can do their jobs. Yet, this does not mean the training contributed to their abilities in a significant way. To assess training fully, is to ask how each stage of training contributes to mission accomplishment.***

3. Reference the list of suggested training measures and DRs.

> ***Measures and DRs commonly used to address training are provided below. They should be considered for use on all testing efforts. Programs using a Training COI are not required to include all the measures and DRs below, as not all of them will apply to every system. Conversely, these measures and DRs may not cover the full scope of data needed to be gathered for every system.***

a. **Measure:** Operator training prepares personnel to operate the system.
Criterion: Yes.

> ***This is the simplest training Measure of Effectiveness (MOE), used mostly when a training COI is not written and SUT training is basic. Link it to effectiveness subtasks, the most operator-intensive task for operation of the system. More specific forms of this measure can be generated. Consider writing versions for separate missions, or separate major tasks. This measure is probably too broad for a SUT with a training COI.***
>
> ***DRs with no highlighting should almost always be used with the associated measure. DRs highlighted blue are less commonly used. DRs highlighted gray will probably only apply in unique cases.***

Data Requirements
OTD review and assessment of operations manuals, operator training manuals and courseware (Qualitative) FROM OTD Review
Operations training progression (schoolhouse/follow-on/On-the-Job Training (OJT)/ proficiency), execution (syllabus/duration/billets), and materials (courseware/equipment/devices/aids/facilities), have been identified/resourced/implemented (Qualitative) FROM NTSP Review
Initial install operator training and/or train-the-trainers training planned and resources (Qualitative) FROM OTD Review
Assessment of training efficiency/quality (Qualitative) FROM Operator Training Interview
Auditing of operator schoolhouse training (Qualitative) FROM OTD Observation
Assessment of operator onboard training (Qualitative) FROM OTD Observation

Data Requirements
Trainer assessment of operator training efficiency/quality (Qualitative) FROM Trainer Interview
Operators successfully trained over observation period (Number) FROM Schoolhouse Records
Operators slated to be trained over observation period (Number) FROM Schoolhouse Records
Navy Training System Plan signed and funded (Qualitative) FROM OTD Review
System/mission experience prior to training (Qualitative) FROM Operator Training Interview
Time in Fleet using system since training (Months) FROM Operator Training Interview
Time since training (Months) FROM Operator Training Interview
Evaluation of training's contribution to skill (Qualitative) FROM Operator Training Interview
Evaluation of prior experience's contribution to skill (Qualitative) FROM Operator Training Interview
Evaluation of OJT contribution to skill (Qualitative) FROM Operator Training Interview

b. **Measure:** Maintenance training prepares personnel to maintain the system.
Criterion: Yes.

This is the basic training Measure of Suitability (MOS); apply to maintenance COI/subtasks, the most operator-intensive task for maintenance of the system. This measure may be too broad for a SUT with a training COI.

Data Requirements
OTD review and assessment of technical manuals, maintenance training manuals and courseware (Qualitative) FROM OTD Review
Maintenance training progression (schoolhouse/follow-on/OJT/ proficiency), execution (syllabus/duration/billets), and materials (courseware/equipment/devices/aids/facilities), have been identified/resourced/implemented (Qualitative) FROM NTSP Review
Maintenance train-the-trainers training planned and resourced (Qualitative) FROM OTD Review
Assessment of training efficiency/quality (Qualitative) FROM Maintainer Training Interview
Auditing of maintainer schoolhouse training (Qualitative) FROM OTD Observation
Assessment of maintainer onboard training (Qualitative) FROM OTD Observation
Assessment of maintenance training efficiency/quality (Qualitative) FROM Trainer Interview
Maintenance personnel successfully trained over observation period (Number) FROM Schoolhouse Records
Maintenance personnel slated to be trained over observation period (Number) FROM Schoolhouse Records
Navy Training System Plan signed and funded (Qualitative) FROM OTD Review
System experience prior to training (Qualitative) FROM Maintainer Training Interview
Time in Fleet using system since training (Months) FROM Maintainer Training Interview
Time since training (Months) FROM Maintainer Training Interview
Evaluation of training's contribution to skill (Qualitative) FROM Maintainer Training Interview

4. Reference the list of additional Availability measures and DRs.

Unlike #3 above, these measures are less likely to apply. They are included as additional brainstorming help for programs, and to help develop DRs, when one of these measures is appropriate.

a. **Measure:** Schoolhouse training prepares operators for system operation.
Criterion: Yes.

MOE (unless there is a COI). Look solely at the benefits of formal operations training within the structured curriculum.

Data Requirements
Operator proficiency test scores before training (Percentage) FROM Proficiency Exam
Operator proficiency test scores after training (Percentage) FROM Proficiency Exam
Operator proficiency test scores at 6 months from training (Percentage) FROM Proficiency Exam
Operator PQS status at 6 months from training (Qualitative) FROM Operator Qualification Record
Problems witnessed during OTD auditing of operator schoolhouse training (Qualitative) FROM OTD Observation
Operators successfully trained over observation period (Number) FROM Schoolhouse Records
Operators slated to be trained over observation period (Number) FROM Schoolhouse Records

Data Requirements
Schoolhouse training failure causes/reasons (Qualitative) FROM Schoolhouse Records
Assessment of training content immediately following training (Qualitative) FROM Operator Training Interview
Assessment of training content at 6 months from training (Qualitative) FROM Operator Training Interview
Assessment of operator training content (Qualitative) FROM Trainer Interview
Assessment of operator training content (Qualitative) FROM OTD Observation
Recommendations for additional training content (Qualitative) FROM Operator Training Interview
Recommendations for additional operator training content (Qualitative) FROM Trainer Interview
Recommendations for additional operator training content (Qualitative) FROM OTD Observation
Assessment of training pace/length immediately following training (Qualitative) FROM Operator Training Interview
Assessment of operator training pace/length (Qualitative) FROM Trainer Interview
Assessment of operator training pace/length (Qualitative) FROM OTD Observation
Assessment of training presentation/format immediately following training (Qualitative) FROM Operator Training Interview
Assessment of operator training presentation/format (Qualitative) FROM Trainer Interview
Assessment of operator training presentation/format (Qualitative) FROM OTD Observation
Assessment of operator proficiency exam content correlation to vital skills (Qualitative) FROM Operator Training Interview
Assessment of operator proficiency exam content correlation to vital skills (Qualitative) FROM Trainer Interview
Assessment of operator proficiency exam content correlation to vital skills (Qualitative) FROM Trainer Interview
System/mission experience prior to training (Qualitative) FROM Operator Training Interview
Time in Fleet using system since training (Months) FROM Operator Training Interview
Time since training (Months) FROM Operator Training Interview
Evaluation of training's contribution to skill (Qualitative) FROM Operator Training Interview
Evaluation of prior experience's contribution to skill (Qualitative) FROM Operator Training Interview
Evaluation of OJT contribution to skill (Qualitative) FROM Operator Training Interview
Aspects of witnessed schoolhouse training not representative of final Fleet product (Qualitative) FROM Trainer Interview
Aspects of witnessed schoolhouse training not representative of final Fleet product (Qualitative) FROM OTD Observation
Aspects of witnessed schoolhouse training not representative of final Fleet product (Qualitative) FROM Program Office

b. **Measure:** Schoolhouse training prepares maintainers for system upkeep.
Criterion: Yes.

MOS. Look solely at the benefits of formal maintenance training within the structured curriculum. The DRs for this measure are similar to those of the schoolhouse MOE.

c. **Measure:** Simulator training prepares new operators and maintains operator proficiency.
Criterion: Yes.

MOE (unless there is a COI). Simulators here could be dive trainers, flight simulators, surface VSIMs, onboard team trainers, etc. It may be worth looking at simulator suitability (RML&A) in addition to trainer effectiveness.

Data Requirements
Problems witnessed during auditing of simulator training (Qualitative) FROM OTD Observation
Simulator uptime FROM Simulator Operations Logs
Simulator downtime FROM Simulator Operations Logs
Simulator reliability failure modes FROM Simulator Operations Logs
Assessment of simulator inaccuracies (Qualitative) FROM Operator Training Interview
Assessment of simulator inaccuracies (Qualitative) FROM Trainer Interview
Assessment of simulator inaccuracies (Qualitative) FROM OTD Observation
Trainer inaccuracies (Qualitative) FROM Program Office
Assessment of ways the simulator does not fully exercise the mission (Qualitative) FROM Operator Training Interview
Assessment of ways the simulator does not fully exercise the mission (Qualitative) FROM Trainer Interview
Assessment of ways the simulator does not fully exercise the mission (Qualitative) FROM OTD Observation
Assessment of simulator instructions/usability (Qualitative) FROM Operator Training Interview
Assessment of simulator instructions/usability (Qualitative) FROM Trainer Interview
Assessment of simulator instructions/usability (Qualitative) FROM OTD Observation

Data Requirements
System/mission experience prior to simulator use (Months) FROM Operator Training Interview
Time in Fleet using system (Months) FROM Operator Training Interview
Time in Fleet using system (Months) FROM Trainer Interview
Wait time to use simulator (Days) FROM Simulator Appointment Logs
Simulator throughput of personnel (Number/Day) FROM Simulator Appointment Logs
Number of simulators on hand (Number) FROM Program Office
Number of simulators planned (Number) FROM Program Office

d. **Measure:** Onboard training provides for maintaining operator proficiency.
Criterion: Yes.

MOE (unless there is a COI). This measure is about division training and personal training, not drills/simulations. Include locations to train, equipment used to train, content of training, etc.

Data Requirements
Problems witnessed during auditing of onboard training (Qualitative) FROM OTD Observation
Training equipment uptime FROM Training Equipment Logs
Training equipment downtime FROM Training Equipment Logs
Training equipment failure modes FROM Training Equipment Logs
Onboard training accuracy (Qualitative) FROM Operator Training Interview
Onboard training accuracy (Qualitative) FROM OTD Observation
Onboard training completeness (Qualitative) FROM Operator Training Interview
Onboard training completeness (Qualitative) FROM OTD Observation
Onboard training accessibility (Qualitative) FROM Operator Training Interview
Onboard training accessibility (Qualitative) FROM OTD Observation
Onboard training equipment usability (Qualitative) FROM Operator Training Interview
Onboard training equipment usability (Qualitative) FROM OTD Observation
Training space availability (Qualitative) FROM Operator Training Interview
Training space availability (Qualitative) FROM OTD Observation
Training workload (Qualitative) FROM Operator Training Interview
Training workload (Qualitative) FROM OTD Observation

e. **Measure:** Personnel Qualification Standards (PQS) establish a path to ensure qualified operators are capable of system operation.
Criterion: Yes.

MOE (unless there is a COI).

Data Requirements
PQS completeness (Qualitative) FROM Operator Training Interview
PQS completeness (Qualitative) FROM OTD Observation
PQS workload (Qualitative) FROM Operator Training Interview
PQS workload (Qualitative) FROM OTD Observation
Average time to qualify (Days) FROM Qualification Records
Qualified personnel (Number) FROM Qualification Records
Unqualified personnel (Number) FROM Qualification Records
Required qualified personnel (Number) FROM Qualification Records
Reasons for qualification delays (Qualitative) FROM Operator Training Interview
Reasons for qualification delays (Qualitative) FROM OTD Observation

f. **Measure:** PQS establish a path to ensure qualified maintainers are capable of system upkeep.
Criterion: Yes.

MOS. DRs for this measure are similar to those above.

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APPENDIX F - Formulae

This appendix summarizes formulae used throughout this handbook, organized by COI.

Reliability

$$MTBOMF = \frac{Total\ System\ Operating\ Time}{Number\ of\ OMFs}$$ (Formula 2-1)

$$R = e^{\left(\frac{-t}{MTBOMF}\right)}$$ (Formula 2-2)

$$MFHBOMF = \frac{Total\ Flight\ Hours}{Number\ of\ OMFs}$$ (Formula 2-3)

$$MTBOMF_{HW} = \frac{Total\ System\ Operating\ Time}{Number\ of\ HW\ OMFs}$$ (Formula 2-4)

$$MTBOMF_{SW} = \frac{Total\ System\ Operating\ Time}{Number\ of\ SW\ OMFs}$$ (Formula 2-5)

$$MTBOMF_{SYS} = \frac{Total\ System\ Operating\ Time}{Number\ of\ HW\ and\ SW\ OMFs}$$ (Formula 2-6)

$$R = \frac{Number\ of Missions\ without\ an\ OMF}{Total\ Number\ of\ Missions}$$ (Formula 2-7)

$$MTBF = \frac{Total\ System\ Operating\ Time}{Number\ of\ Failures}$$ (Formula 2-8)

$$R_{X,Y,Z} = e^{\left(\frac{-t_{x,y,z}}{MTBF}\right)}$$ (Formula 2-9)

$$R_{SUT} = 1 - (1 - R_X) * (1 - R_Y) * (1 - R_Z)$$ (Formula 2-10)

$$MTBOMF_{MA} = \frac{Total\ [MA] System\ Operating\ Time}{Number\ of\ [MA] OMFs}$$ (Formula 2-11)

$$R_{MA} = e^{\left(\frac{-t_{MA}}{MTBOMF_{MA}}\right)}$$ (Formula 2-12)

$$MTBUM/MFHBUM = \frac{Total\ System\ Operating\ Time\ (Flight\ Hours)}{Number\ of\ Unscheduled\ Maintenance\ Actions}$$ (Formula 2-13)

$$MTBA/MFHBA = \frac{Total\ System\ Operating\ Time\ (Flight\ Hours)}{Number\ of\ Mission\ Aborts} \quad \text{(Formula 2-14)}$$

$$R_{SUT} = R_X * R_Y * R_Z \quad \text{(Formula 2-15)}$$

$$MTBOMF = \frac{Total\ \#\ of\ Operating\ Hours}{X\ OMFs + Y\ OMFs + Z\ OMFs} \quad \text{(Formula 2-16)}$$

Maintainability

$$MCMTOMF_{HW} = \frac{Total\ Elapsed\ Time\ to\ Correct\ HW\ OMFs}{Total\ Number\ of\ HW\ OMFs} \quad \text{(Formula 3-1)}$$

$$MTTR_{HW} = \frac{Total\ Elapsed\ Time\ to\ Correct\ All\ HW\ Failures}{Total\ Number\ of\ HW\ Failures} \quad \text{(Formula 3-2)}$$

$$MCMTOMF_{SW} = \frac{Total\ Elapsed\ Time\ to\ Restore\ System\ after\ OMFs}{Total\ Number\ of\ SW\ OMFs} \quad \text{(Formula 3-3)}$$

$$MCMTOMF_{SYS} = \frac{Total\ Elapsed\ Time\ to\ Correct\ OMFs}{Total\ Number\ of\ HW\ and\ SW\ OMFs} \quad \text{(Formula 3-4)}$$

$$MTTR_{SW} = \frac{Total\ Elapsed\ Time\ to\ Correct\ All\ SW\ Faults}{Total\ Number\ of\ SW\ Faults} \quad \text{(Formula 3-5)}$$

$$MRT = \frac{Total\ Elapsed\ Time\ to\ Reboot\ a\ SW\ Intensive\ System}{Total\ Number\ of\ SW\ Reboots} \quad \text{(Formula 3-6)}$$

$$MPMT = \frac{Total\ Elapsed\ Time\ to\ Complete\ PM}{Total\ Number\ of\ PM\ Actions} \quad \text{(Formula 3-7)}$$

$$P_{CFD} = \frac{Number\ of\ Failures/Faults\ Correctly\ Detected\ by\ BIT}{Number\ of\ Actual\ System\ Failures/Faults} \quad \text{(Formula 3-8)}$$

$$P_{CFI} = \frac{Number\ of\ Failures/Faults\ Correctly\ Isolated\ by\ BIT}{Total\ Number\ of\ Failures/Faults\ Correctly\ Detected\ by\ BIT} \quad \text{(Formula 3-9)}$$

$$P_{BFA} = \frac{Number\ of\ Incorrect\ BIT\ /\ Fault\ Indication}{Total\ Number\ of\ BIT\ Failure/Fault\ Indications} \quad \text{(Formula 3-10)}$$

$$BFAh = \frac{Number\ of\ Incorrect\ BIT\ /\ Fault\ Indication}{Total\ Number\ of\ Operating\ Hours} \quad \text{(Formula 3-11)}$$

$$MTBBFA = \frac{Total\ System\ Operating\ Time}{Number\ of\ Incorrect\ BIT\ /\ Fault\ Indication} \quad \text{(Formula 3-12)}$$

$$MaxCMTOMF = the\ time\ below\ which\ a\ specified\ percentage\ of\ corrective\ maintenance\ tasks\ must\ be\ completed\ to\ restore\ the\ system\ to\ operation\ after\ an\ OMF \quad \text{(Formula 3-13)}$$

$$MR = \frac{\substack{Total\ Maintenance\ Man{-}Hours\ to\ Accomplish\ Required \\ Preventative\ Maintenance\ and\ Repair\ all\ Failures}}{Total\ System\ Operating/Flight\ Hours} \quad \text{(Formula 3-14)}$$

Logistic Supportability

$$MLDTOMF = \frac{Total\ Elapsed\ Tme\ SUT\ is\ Awaiting\ Off{-}board\ Logistics\ to\ Correct\ OMFs}{Total\ Number\ of\ OMFs\ requiring\ Off{-}board\ Logistics\ Actions} \quad \text{(Formula 4-1)}$$

$$MLDT = \frac{Total\ Elapsed\ Tme\ SUT\ is\ Awaiting\ Offboard\ Logistics}{Total\ Number\ of\ Logistics\ Actions} \quad \text{(Formula 4-2)}$$

Availability

$$A_O = \frac{Uptime}{Uptime + Downtime} \quad \text{(Formula 5-1)}$$

$$A_O = \frac{(SOT + ST) + Offtime}{(OT + ST) + Offtime + Downtime} \quad \text{(Formula 5-2)}$$

$$A_O = \frac{(SOT + ST)}{(OT + ST) + Downtime} \quad \text{(Formula 5-3)}$$

$$A_{OD} = \frac{Number\ of\ times\ the\ systems\ was\ available}{Number\ of\ times\ the\ systems\ was\ required} \quad \text{(Formula 5-4)}$$

$$FMC = \frac{Uptime_{FMC}}{Uptime_{FMC} + Downtime_{FMC}} \quad \text{(Formula 5-5)}$$

$$PMC = \frac{Uptime_{PMC}}{Uptime_{PMC} + Downtime_{PMC}} \quad \text{(Formula 5-6)}$$

$$MC_{MA} = \frac{Uptime_{MA}}{Uptime_{MA} + Downtime_{MA}} \quad \text{(Formula 5-7)}$$

$$A_a = \frac{SOT}{SOT + (Downtime\ due\ to\ CMT\ \&\ PMT\ only)} \quad \text{(Formula 5-8)}$$

$$A_i = \frac{SOT}{SOT + (Downtime\ due\ to\ CMT\ only)} \quad \text{(Formula 5-9)}$$

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APPENDIX G - Acronyms

Aa	Achieved Availability
ACR	Allowance Change Request
ACWT	Average Customer Wait Time
AdmDT	Administrative Delay Time
AEL	Allowance Equipage List
Ai	Inherent Availability
ALDT	Administrative and Logistic Delay Time
A_M	Material Availability
A_O	Operational Availability
A_{OD}	On-Demand Availability
APL	Allowance Parts List
APML	Assistant Program Manager for Logistics
APU	Auxiliary Power Unit
AT	Adjunct Tester
AVCAL	Aviation Consolidated Allowance List
AW	Air Warfare
BFA	BIT False Alarm
BFAh	BIT False Alarms per hour
BIT	Built In Test
C2	Command and Control
CAP	Corrective Action Plan
CDD	Capabilities Development Document
CDR	Critical Design Review
CLS	Contractor Logistics Support
CME	Corrective Maintenance Event
CMT	Corrective Maintenance Time
COI	Critical Operational Issue
CONOPS	Concept of Operations
COSAL	Consolidated Shipboard Allowance List
CS	Combat System
DAAS	Defense Automatic Addressing System
DAU	Defense Acquisition University
DC	Data Collector
DCN	Design Change Notice
DCP	Data Collection Plan
D-Level	Depot Level
DMSMS	Diminishing Manufacturing Sources and Material Shortages

DoD	Department of Defense
DOT&E	Director, Operational Test and Evaluation
DR	Data Requirement
DRM	Design Reference Mission
DRRS-N	Defense Readiness Reporting System-Navy
DT	Developmental Test
DTO	Direct Turnover
EFF	Essential Function Failure
ELINT	Electronic Intelligence
EOA	Early Operational Assessment
FID	Fault Isolate and Detect
FMC	Full Mission Capable
FOT&E	Follow-on Test and Evaluation
FSR	Field Service Representative
HW	Hardware
IEF	Integrated Evaluation Framework
IETM	Interactive Electronic Technical Manual
ILA	Independent Logistics Assessment
I-Level	Intermediate Level
ILSP	Integrated Logistic Support Plan
IMEC	Item Mission Essential Code
INCO	Installation and Check-Out
IOC	Initial Operational Capability
IOT&E	Initial Operational Test and Evaluation
IP	Intellectual Property
IPR	In Process Review
ISEA	In-Service Engineering Agent
IT	Integrated Testing
IWST	Integrated Weapon Support Team
KPP	Key Performance Parameter
LCL	Lower Confidence Limit
LCS	Littoral Combat Ship
LCSP	Life Cycle Sustainment Plan
LDT	Logistics Delay Time
LMARS	Logistics Metrics Analysis Reporting System
Log-Demo	Logistics Demonstration
LRT	Logistics Response Time

LRU	Line Replaceable Units
LTE	Lead Test Engineer
MaxCMTOMF	Maximum Corrective Maintenance Time for Operational Mission Failure
MBTD	Mission Based Test Design
MC_{MA}	Mission Capability by Mission Area
$MCMTOMF_{HW}$	Mean Corrective Maintenance Time, Operational Mission Failure, Hardware
$MCMTOMF_{SW}$	Mean Corrective Maintenance Time, Operational Mission Failure, Software
$MCMTOMF_{SYS}$	Mean Corrective Maintenance Time, Operational Mission Failure, System
MCR	Mission Completion Rate
MCSM	Mission-Critical Subsystem Matrix
M-DEMO	Maintenance Demonstration
MDT	Maintenance Delay Time
MEF	Mission Essential Function
MESM	Mission Essential Subsystem Matrix
MIW	Mine Warfare
MLDT	Mean Logistic Delay Time
MOA	Memorandum of Agreement
MOB	Mobility
MOE	Measure of Effectiveness
MOS	Measure of Suitability
MOT&E	Multi-service Operational Test and Evaluation
MR	Maintenance Ratio
MRBOMF	Mean Rounds Between Operational Mission Failure
MRC	Maintenance Requirement Card
MRT	Mean Reboot Time
MFHBA	Mean Flight Hours Between Mission Aborts
MFHBOMF	Mean Flight Hours Between Operational Mission Failures
MFHBUM	Mean Flight Hours Between Unscheduled Maintenance
MSD	Material Support Date
MTBA	Mean Time Between Mission Aborts
MTBBFA	Mean Time Between Bit False Alarms
MTBOMF	Mean Time Between Operational Mission Failure
MTBUM	Mean Time Between Unscheduled Maintenance
MTTR	Mean Time to Repair
NAVSUP	Navy Supply Systems Command
NALCOMIS	Naval Aviation Logistics Command Management Information Systems
NIIN	National Item Identification Number
NSN	National Stock Number
O&S	Operations & Sustainment
OA	Operational Assessment

OADT	Outside Assistance Delay Time
OBRP	Onboard Repair Part
OEM	Original Equipment Manufacturer
OER	Operational Evaluation Report
OJT	On-the-Job Training
O-Level	Organizational Level
OMF	Operational Mission Failure
OPNAV	Office of the Chief of Naval Operations
OPNAVINST	Office of the Chief of Naval Operations Instruction
OPTEMPO	Operational Tempo
OPTEVFOR	Operational Test and Evaluation Force
OT	Operational Testing
OTA	Operational Test Agency
OTC	Operational Test Coordinator
OTD	Operational Test Director
OTRR	Operational Test Readiness Review
OTSB	Operational Test Scoring Board
P_{BFA}	Probability of BIT False Alarm
P_{CFD}	Probability of Correct Fault Detection
P_{CFI}	Probability of BIT Correct Failure/Fault Isolation
PMC	Partial Mission Capability
PMS	Planned Maintenance System
PMT	Preventive Maintenance Time
POM	Program Objective Memorandum
PQS	Personnel Qualification Standard
PSP	Product Support Package
QA	Quality Assurance
R&R	Remove and Replace
R (MR)	Reliability (Mission Reliability)
RBD	Reliability Block Diagram
R_{MA}	Reliability by Mission Area
RM&L	Reliability, Maintainability and Logistic Supportability
RML&A	Reliability, Maintainability, Logistic Supportability, and Availability
RMWS	Ramp Mounted Weapon System
RSSP	Replaced System Sustainment Plan
SAS	Stability Augmentation System
SAT	Satisfactory
SERB	System Evaluation Review Board
SOS	System of Systems

SOT	Systems Operating Time
SRT	Supply Response Time
ST	Standby Time
SUT	System Under Test
SUW	Surface Warfare
SW	Software
TEMP	Test and Evaluation Master Plan
TMRR	Technology Maturation and Risk Reduction
TOC	Total Ownership Cost
UNSAT	Unsatisfactory
VCD	Verification of Correction of Deficiencies
WSS	Weapon Support System