Abstract
This paper advocates diagnostics and testing in a "back to basics" way by stressing the importance of establishing goals which are absolutely relevant to operational capabilities and constraints.

The evolution of support methods and concepts for mission equipment has sometimes resulted in the rote application of technology to diagnostics and testing without first establishing the operational relevancy for such support. The trend is insensitive to the fact that maintenance testing is not the primary mission of operational users and that ineffective testing can be more a liability than an asset to the mission.

Without relevant objectives for support tasks, their development can be dominated by technical challenge. The result can be overly complex, ineffective support. This paper highlights a fundamental approach for design and diagnostics to select and balance maintenance tasks and optimize operational support.

...the money has been spent, but there is no real capability...
Activities involving diagnostics, maintenance testing, and replacing parts are a large part of keeping equipment to achieve operational capabilities to perform missions. Although the mission equipment is usually the focus -- the "centerpiece" of any system -- the equipment alone cannot be a capability. For example, an aircraft can be designed for certain air-combat missions, but it is the aircraft and its supporting infrastructure that defines the aircraft as a mission capability which facilitates the user's potential to perform missions.

To perform missions, the aircraft and its support must dynamically interact and this interaction must be efficient and suitable if any capability is to be retained. Ineffective equipment designs and support can reduce potential to the point that it cannot achieve or sustain the dynamics needed for actual missions. If this happens, the "mission" system exists, the money has been spent, but there is no real capability.

Users like self-sufficiency and minimum overhead...
People who develop support for mission equipment should first realize that fixing equipment is not the user's main job. Users fix equipment and stock spare parts -- diagnostics, testing, and supply support -- because mission equipment which requires none of these has not been built. From the user's perspective, diagnostics and maintenance testing are non-operational exceptions to otherwise "ideal" operational capabilities and spares are needed for replacement "fixes." Users want accurate, effective ways of dealing with these exceptions and they want the right spares; users like to be self-sufficient with minimum overhead.

"If it isn't mission related, I don't want it."
Operational commands have prime equipment to accomplish their missions. Maintenance and supply are tolerated as exceptions which keep equipment operational. Unfortunately, people who acquire and develop prime equipment sometimes approach maintenance and supply support as "givens" -- as institutions -- instead of exceptions by concentrating on furnishing support capability instead of supported capability. Back to basics requires efforts to develop mission...
capabilities to first assume support only for consumables (fuel, oil, munitions, etc.), then to conservatively proceed from there.

Support should always be considered a liability...
All "support" requirements for a mission capability should start as liabilities. Then, every support aspect should be an exception and each should be relevant to operational capabilities. This paper proposes that support "problems" would not exist if support constraints were established and every support "requirement" were validated in operationally relevant terms. Liabilities are what the user is willing to invest and tolerate to sustain capability as defined by the user. Operationally relevant validation ensures that only absolutely essential support is deployed and imposed upon the user.

Any testing is a liability until proven as an asset...
Effective diagnostics dictates complete and interrelational analysis of the supported equipment design (and the capability it represents) to define objectives for support testing. Without operationally relevant objectives, there is no valid measure to determine if testing is a liability or an asset. Initially, testing should always be viewed as a liability unless criteria, based on operational capability, can show it to be an asset. To an operational organization, all testing is a liability because things should behave in their normal way for as long as they are needed. Users "use" prime equipment to accomplish objectives -- testing is done to facilitate that use.

Support and mission capabilities compete for resources...
If any particular technology dominates the overall support task involving testing, then the risks of that technology add to the direct risks of the technology being applied to achieve operational capability. When this happens, substantial resources can be consumed achieving the capability of the support resource instead of achieving operational capability. An effort intended to produce a support asset can become a support liability in terms of overall operational capability.

LSA should anchor every task...
Typically, logistics support analysis (or its equivalent) should anchor every technical task involving testing and results of analysis should be available to relate testing to operational requirements. LSA establishes operational relevancy and provides objective criteria for testing tasks. If the technical effort can't relate to LSA, then it may not relate well to operational capabilities.

Testing is to obtain information...
An effective LSA establishes relevancy for all support testing and defines objective purposes and parameters for each test task. Every maintenance task should facilitate a logical sequence of events useful to either assure equipment readiness or return equipment to readiness. The kinds of events and the logic of their sequences must be developed considering the context for their use, their value to operations, and their required outcome. Overall, every sequence of events is meant to provide a logical and correct "conclusion" by obtaining "information" about the "condition" of equipment. A properly conducted LSA serves as the basis for valid test strategies and technological approaches by furnishing context, definitions, and parameters for "information," "condition," and "conclusion."

Each sequence has a definite beginning and a definite conclusion...
Maintenance sequences begin with a determination that some action is required to reach some conclusion (about equipment) which can be related to operational capability and/or mission. Each sequence has a definite beginning and a definite conclusion and each event within the sequence must be just sufficient to achieve its part. Each sequence should be the shortest and most optimum path between the determination and the correct conclusion. The idea is to first design equipment to minimize sequences, then simplify and reduce the
events for each sequence by applying the best of all possible alternatives to each event to achieve the correct conclusion.

How much is enough?
An economic test effort meant for effectiveness qualifies "conditions" of tested items in terms of their use and possible conclusions, then develops test strategies constrained to obtain only enough information to implement "best" conclusions. This modeling is crucial to establish and maintain objective relevancy for sequences and their events. For example, If a testing sequence was developed to conclude with removal and replacement of a failed part, but other operational conditions made such an action impossible, then the sequence is not required because the conclusion is not valid. It is irrelevant that such testing can be accomplished and replacement under other conditions could be accomplished. In the stated situation, no valid conclusion exists to justify the testing sequence. This example illustrates two things: First, that the technically valid sequence is invalidated by operational context and second, this invalidation would not be apparent without analysis involving the operational context.

Eliminate the sequence or alter the context...
In the foregoing example, nothing within the technical task would indicate its validity within any given context. And, in a well conducted analysis effort, the next logical step might be to challenge the operational context (or possibly the equipment design) in an effort to validate the original conclusion. We would evaluate (in the strictest sense of "valuation") the limiting factors of operations and/or equipment design and the conclusion; how badly do we need to replace the defective part. If replacement is determined to be valuable enough, then the original sequence is retained and the context for its use is changed by eliminating the limiting factors.

Different levels of support need different strategies...
The sequences of a support strategy for any given capability should model concentric "levels" of support around a focus of operational capability -- like a target with capability as its center. The level nearest to capability must be virtually 100% effective although highly constrained by time, materiel, and other operational and support factors. At this level, empirical methods, essential and non-complex pass-fail testing, and coordinated, essential materiel support should be primary factors in the sequence.

Use dependency models to engineer empirical methods...
Here, empirical methods mean the use of observation and experience to achieve correct conclusions. "Dependency" modeling techniques can be effectively applied to engineer empirical maintenance sequences. These techniques are used to influence testability and/or "observability" in equipment design and can produce impressive results using only human observation.

Any function is logically dependent on related functions...
Dependency models define functions in terms of other functions upon which they depend for their existence. Their logic is that any given function (as defined) can exist only if its "dependency" functions exist. Since there are no logical limitations on how "function" is defined, the technique can deal with large, complex systems to reduce their function (or any aspect of their function) to related sub-functions which can be further reduced to related sub-functions and so on. In the process, the logic of the technique identifies dependent and "not" dependent functions to the extent that maintenance sequences can identify and concentrate only on key, relevant functions.

Dependency models can guide BIT design...
Dependency model techniques can be used to form and validate any maintenance sequence and to logically determine where observation (or testing) should be applied for maximum effectiveness. Dependency models can also be used during equipment design to enhance observability and/or testability of key functions. If mission equipment is designed for empirical methods by enhancing the observability of key functions, then effective implementation of this
Maintenance method is practically assured. Built-in testing can be especially effective when implemented according to the results of dependency modeling.

Dependency models can validate proposed maintenance methods...
Dependency modeling can reduce or eliminate testing which only leads to interim conclusions (actions) based on "probabilities" of cause. This technique, possibly the least effective of all test technologies, requires replacement of parts based upon a derived probability that they have failed. This approach, amounting to little more than rote substitution, is often employed to overcome inadequate testability in the designs of tested equipment. Dependency modeling can be effectively applied to achieve three purposes: First, it can "evaluate" and predict the outcome of any proposed attempt to test the equipment to achieve valid conclusions. Second, it can indicate where different testing techniques could be useful to achieve effective results despite the equipment design. Third, it can indicate where changes to the equipment design could increase test effectiveness.

The user needs suitable conclusions, not complex testing...
If external testing must be employed, then it should be designed to furnish useful information with minimum complexity. The user wants to achieve that suitable conclusion without being challenged by a brilliant, but difficult item of test equipment. Also, if the test equipment can't be fixed when it breaks, then the user loses the ability to achieve the sequence and, at least for a time, the entire sequence is useless.

Discreet values, To test or not...
Some testing sequences are overly complex and difficult because they are designed to obtain far more information than is actually needed to support a suitable conclusion. For example, simple tests to determine "pass - fail" conditions can be more effective than elaborate tests used to determine actual parameters or the discreet values of failed functions. Maintenance sequences should not require measurement of discreet values unless they are necessary to achieve suitable conclusions. Completely suitable conclusions can be obtained by discovering out-of-tolerance parameters without ever determining their extent.

Any suitable conclusion must be supported...
All the empirical observations, design for testability, and testing don't do much unless users can actually perform actions required to obtain suitable conclusions. Possibly the most neglected aspect of suitable conclusions is supply support -- spare parts. Ideally, a sound approach to diagnostics, LSA, and supply support planning will ensure that a spare is available to facilitate every conclusion requiring a replacement action. This process can determine a "range" of spares, while equipment reliability (along with other factors of consumption) will determine the "levels" of spares. The reader should not confuse this with "100% sparing" or "A planeload of spares can support anything." Both approaches are wasteful and neither is popular with materiel managers or users.

Spares that don't support conclusions are just stuff...
Well managed, relevant maintenance sequences require discreet spares levels and ranges and attempts to reduce (sometimes called "optimize") either will decrease the effectiveness of maintenance sequences. This paper will not attempt a full discussion of spares "optimization," except to caution that it is risky, complicated, and well worth avoiding. When spares are directly linked to effective maintenance conclusions, failure probabilities and other such "factors" should be used to prioritize spares procurements, but they should not be used to justify not procuring spares. Nobody gets too upset about spares which are effective for concluding sequences and every spare should relate to a sequence conclusion. Otherwise, "spares" are just stuff.

The challenge is operational capability, not maintenance testing...
The user needs suitable conclusions, not complex tasking. When spares are directly linked to effective maintenance conclusions, failure probabilities and other such "factors" should be used to prioritize spares procurements, but they should not be used to justify not procuring spares. Nobody gets too upset about spares which are effective for concluding sequences and every spare should relate to a sequence conclusion. Otherwise, "spares" are just stuff.

To conclude, the attitudes shaping mission equipment availability should not assume diagnostics and maintenance testing, but rather strive for absolutely minimum and effective support to ensure operational capabilities. A "back to
basics" approach should dominate diagnostics and maintenance testing, emphasizing operational capability and maintenance as a liability instead of an asset. The relevancy of diagnostics and maintenance tasks can be lost in their technical challenges and the result can be overly complex, ineffective maintenance efforts which can only waste resources and degrade operational effectiveness.