APPENDIX D

DESIGN REVIEW CHECKLIST

Periodically, throughout the system design and development process, it is appropriate to conduct an informal review to (1) determine whether the necessary tasks have been completed in a given program to ensure optimum results overall, and (2) assess whether the appropriate characteristics have been considered and incorporated into the system/product design configuration. Questions, presented in the form of a checklist, have been developed to reflect certain features. System-level requirements and detailed design considerations are included. Not all questions are applicable in all reviews; however, the answer to those questions that are applicable should be "yes" in order to reflect desirable results. For some questions, it may be necessary to pursue a more in-depth study of the subject through a review of selected references prior to arriving at a decision. These questions directly support the abbreviated checklist presented in Figure 5.4 (Chapter 5).

D.1 GENERAL REQUIREMENTS

1.0 Feasibility Analysis

1.1 Has the "need" for the system/product been defined and justified?

1.2 Has the overall technical design approach for the system been justified through a feasibility analysis?

1.3 In the conductance of the feasibility analysis, have *all* appropriate technology applications been considered and prioritized in the development of a technical design approach for the system?

1.4 Have *existing* technologies been selected where feasible, as compared with the selection of new state-of-the-art technologies?

1.5 In the evaluation of alternative technology applications, have life-cycle cost considerations been employed? Have peculiar support requirements been identified?

1.6 Will the technologies selected be available in time to meet program schedule requirements?

1.7 Are there multiple sources of supply for each of the technologies selected for application (i.e., more than one supplier)?

1.8 Have research-and-development activities been defined for areas where deficiencies exist?

1.9 Have areas of risk and uncertainty been identified?

2.0 Operational Requirements

2.1 Has the mission for the system been defined (i.e., primary and secondary missions with applicable scenarios or profiles)?

2.2 Have system performance requirements been defined?

2.3 Have the technical performance measures (TPMs) for the system/program been identified, described, and prioritized? Are they measurable?

2.4 Has the system/product life cycle, and the major activities within, been adequately defined (i.e., design and development, production and/or construction, distribution, operational use, sustaining support, retirement and disposal)?

2.5 Has the planned operational deployment, or the geographical distribution of system components, been defined (i.e., customer requirements, quantity of items per "user" location, distribution schedule)?

2.6 Have system utilization requirements been defined? These may include projected hours of system operations, or quantity of operational cycles in a given time period. A "dynamic" operational scenario is desired.

2.7 Has the projected operational environment been adequately described in terms of temperature cycles and extremes, humidity, vibration and shock, storage, transportation and handling?

3.0 Maintenance Concept

3.1 Have the anticipated levels of maintenance been identified and defined?

3.2 Have the basic maintenance functions been identified for each level?

3.3 Have the organizational responsibilities for system maintenance and support been assigned (i.e., user support, contractor support, supplier support, third-party maintenance)?

3.4 Have level-of-repair policies been established (i.e., repair versus discard)? Have the criteria for level-of-repair decisions been adequately defined?

3.5 Have the requirements for "standardization" been established (as it applies to the overall system support capability)?

3.6 Have criteria been established for personnel quantities and/or skills at each level of maintenance?

3.7 Have criteria been established for test and support equipment at each level of maintenance? Built-in versus external test equipment? Diagnostic requirements?

3.8 Have software requirements for system and/or component testing been defined? Test language requirements?

3.9 Have criteria been established for maintenance facilities?

3.10 Have criteria been established for packaging, transportation, and handling?

3.11 Have the appropriate effectiveness factors been established for design for the overall support capability (i.e., spare part demand rates, inventory locations and levels, test equipment availability and utilization, maintenance shop queue and process time, facility utilization, turnaround time, and so on)?

3.12 Have the maintenance and support environments been defined in terms of temperature cycle and extremes, humidity, vibration and shock, transportation and handling, and storage?

4.0 Effectiveness Factors

4.1 Have the appropriate system effectiveness and cost-effectiveness figures of merit (FOMs) been defined for the system/product (i.e., availability, dependability, capability, readiness, life-cycle cost, design to cost)?

4.2 Have applicable quantitative factors for reliability, maintainability, human factors, and supportability been specified, i.e., MTBM, MTBR, MTBF, λ, fpt, MDT, $\bar{M}$, ADT, LDT, $\bar{M}ct$, $\bar{M}pt$, MLH/OH, Cost/OH, Cost/MA, TAT? For an explanation of these terms, refer to chapter 3.

4.3 Are the effectiveness factors that have been specified directly traceable to either the system operational requirements (mission scenario) or the maintenance concept?

4.4 Can each of the effectiveness factors identified for the system be measured? Have test and evaluation provisions been incorporated in the Test and Evaluation Master Plan (TEMP) for the purposes of verification?

4.5 In the event that two or more effectiveness measures are applicable, are the measures properly weighted to indicate degree of significance or relative level of importance?

4.6 Are all significant effectiveness FOMs properly integrated into the TPM evaluation and reporting capability?

5.0 Functional Analysis and Allocation

5.1 Has the system/product been adequately defined in *functional* terms utilizing the functional block diagram approach?

5.2 Have all major system operational functions and maintenance functions been defined?

5.3 Does the functional analysis evolve directly from the system operational requirements and the maintenance concept? Are the functions directly traceable to top system-level requirements (i.e., the mission scenario)?

5.4 Do the maintenance functions evolve directly from the operational functions?

5.5 Is the functional analysis presented in enough detail to allow for the proper development of the reliability block diagram, fault-tree analysis (FTA), failure mode, effects, and criticality analysis (FMECA), maintainability prediction, maintenance analysis, detailed operator task analysis, operational sequence diagrams, safety hazard analysis, and supportability analysis (SA)?

5.6 Is the functional analysis presented in enough detail for development of the system specification?

5.7 Have the appropriate system-level requirements been allocated to the depth necessary for adequate design definition (i.e., subsystem level and below)? This may include the allocation of reliability requirements, maintainability requirements, supportability factors, and cost parameters.

5.8 In the allocation of factors from the system to the subsystem, unit, and below, are the parameters traceable from one level to the next? Are the parameters meaningful in terms of being good measures for the level of the system specified?

6.0 System Specification

6.1 Has a program/project specification tree been developed (showing governing specifications presented in a hierarchal manner)?

6.2 Has a system specification been prepared (i.e., Type "A" Specification)?

6.3 Have the appropriate development, procurement, process, and material specifications been prepared (i.e., Types "B," "C," "D," and "E")?

6.4 Does the system specification include operating requirements, the maintenance concept, a functional definition of the system, and effectiveness requirements (i.e., reliability, maintainability, human factors, safety, supportability, economic, and quality factors)?

6.5 Are the various specifications that are applicable compatible with each other? Have conflicting specification requirements been eliminated? If not, has precedence been established?

7.0 Supplier Requirements[1]

7.1 Have the criteria and procedures for the initial identification, evaluation, and selection of component suppliers been established?

7.2 Have all component suppliers been identified? Has an on-site evaluation been conducted for each potential supplier?

[1]Also refer to Appendix E.

7.3 Have supplier specifications been prepared and properly applied through the appropriate contractual arrangements?

7.4 Have individual supplier program plans been prepared and implemented?

7.5 Are supplier design data and documentation compatible with the requirements for the overall program?

7.6 Have the appropriate configuration management procedures been imposed on supplier design and development activities?

7.7 Have the appropriate quality control procedures been established for the ongoing monitoring and control of supplier activities? Has a supplier rating system been implemented for the purposes of evaluation?

8.0 System Engineering Management Plan (SEMP)

8.1 Has the System Engineering Management Plan (SEMP) been developed?

8.2 Does the SEMP address the overall system life cycle and its phases/activities?

8.3 Does the plan adequately describe the system engineering process?

8.4 Does the plan convey the proper integration of the different engineering specialties involved in the system/product design process?

8.5 Does the SEMP properly integrate other plans such as the Reliability Program Plan, Maintainability Program Plan, Human-Factors Program Plan, Safety and Security Engineering Plan, Integrated and Logistic Support (ILS) Plan, Logistics and Supportability Analysis Plan, Configuration Management Plan, Test and Evaluation Master Plan (TEMP), and so on?

8.6 Have major system trade-off studies been adequately documented, and are they appropriately referenced in the SEMP?

8.7 Does the SEMP adequately support the system specification?

8.8 Are program tasks, organizational structure and responsibilities, work breakdown structure (WBS), schedules, cost projections, and program monitoring and control functions included?

8.9 Have a personnel development plan and an organizational training plan been included?

8.10 Have supplier program requirements been covered?

8.11 Have formal design reviews been covered? Has a formal system evaluation and corrective-action procedure been described and implemented?

Additional questions pertaining to the SEMP are included in Section 6.2 (Chapter 6).

D.2 DESIGN FEATURES

1.0 Accessibility

1.1 Are key system components directly accessible for the performance of both operator and maintenance tasks?

1.2 Is access easily attained?

1.3 Are access requirements compatible with the frequency of maintenance (or criticality of need)? Accessibility for items requiring frequent maintenance should be greater than for items requiring infrequent maintenance.

1.4 Are access doors provided where appropriate? Are hinged doors utilized? Can access doors that are hinged be supported in the open position?

1.5 Are access openings adequate in size and optimally located for the access required?

1.6 Are access door fasteners minimized?

1.7 Are access door fasteners of the quick-release variety?

1.8 Can access be attained without the use of tools?

1.9 If tools are required to gain access, is the number of tools held to a minimum? Are the tools of the standard variety?

1.10 Are access provisions between modules and components adequate?

1.11 Are access doors and openings labeled in terms of items that are accessible from within?

2.0 Adjustments and Alignments

2.1 Have adjustment/alignment requirements been minimized, if not eliminated?

2.2 Are adjustment requirements and frequencies known where applicable?

2.3 Are adjustment points accessible?

2.4 Are adjustment-point locations compatible with the maintenance level at which the adjustment is made?

2.5 Have adjustment/alignment interaction effects been eliminated?

2.6 Are factory adjustments specified?

2.7 Are adjustment points adequately labeled?

2.8 Can adjustments/alignments be made without the requirement for special tools?

3.0 Cables and Connectors

3.1 Are cables fabricated in removable sections?

3.2 Are cables routed to avoid sharp bends?

3.3 Are cables routed to avoid pinching?

3.4 Is cable labeling adequate?

3.5 Is cable clamping adequate?

3.6 Are the connectors used of the quick-disconnect variety?

3.7 Are connectors that are mounted on surfaces far enough apart so that they can be firmly grasped for connecting and disconnecting?

3.8 Are connectors and receptables labeled?

3.9 Are connectors and receptables keyed?

3.10 Are connectors standardized?

3.11 Do the connectors incorporate provisions for moisture prevention?

4.0 Calibration

4.1 Have calibration requirements been minimized, if not eliminated?

4.2 Are calibration requirements known where applicable?

4.3 Are calibration frequencies and tolerances known?

4.4 Have the facilities for calibration been identified?

4.5 Are the necessary standards available for calibration?

4.6 Have calibration procedures been prepared?

4.7 Is traceability to the National Institute of Standards and Technology (NIST) possible?

4.8 Are calibration requirements compatible with the maintenance concept and the supportability analysis (SA)?

5.0 Data Requirements

5.1 Has the design been properly defined through good data and documentation (i.e., layouts, drawings, functional diagrams, and materials and parts lists)?

5.2 Are system components adequately covered through good up-to-date design data?

5.3 Have the results of significant design trade-off studies been properly recorded through good documentation?

5.4 Have all data requirements been defined for each applicable program?

5.5 Have all supplier data requirements been defined and properly integrated into the overall data requirements for the program?

5.6 Have the procedures for data collection, distribution, and processing been developed and described?

5.7 Is standardization employed, where appropriate, in data formatting, processing, and reporting?

5.8 Are the data properly controlled in accordance with approved configuration management procedures?

6.0 Disposability

6.1 Has the equipment been designed for disposability (e.g., selection of materials, packaging)?

6.2 Have procedures been prepared to cover system/equipment/component disposal?

6.3 Can the components or materials used in system/equipment design be recycled for use in other products?

6.4 If component/material recycling is not feasible, can decomposition be accomplished?

6.5 Can recycling and/or decomposition be accomplishing using existing logistic support resources?

6.6 Are recycling and/or decomposition methods and results consistent with environmental, ecological, safety, political, and social requirements?

6.7 Is the method(s) used for recycling and/or decomposition economically feasible?

7.0 Ecological Requirements

7.1 Has an environmental impact study been completed (to determine if the system will have an adverse impact on the environment)?

7.2 Are the required standards associated with air quality, water quality, noise level(s), solid-waste processing, and so on, being maintained in spite of the introduction, operation, and sustaining support of the system/product?

7.3 Have potentially degrading ecological effects been identified? Is corrective action being taken to eliminate problems in this area?

7.4 Have the appropriate handling and transportation methods/procedures been described for the processing of solid waste?

8.0 Economic Feasibility

8.1 Has the system/product been justified in terms of total *life-cycle* revenues and costs?

8.2 Are all cost elements considered?

8.3 Are all cost categories adequately defined?

8.4 Are cost estimates relevant?

8.5 Are variable and fixed costs separately identifiable?

8.6 Are escalation factors specified and employed where applicable?

8.7 Are learning curves specified and employed where applicable?

8.8 Is the project economically feasible, considering all possible alternatives?

8.9 Is *activity-based costing* (ABC) used in determining costs?

9.0 Environmental Requirements

9.1 Has system/product design considered all possible phases of activity from an environmental standpoint; for example, environmental requirement during system handling, operation/utilization, transportation, storage, and maintenance?

9.2 Has system/product design considered the following: temperature, humidity, vibration, shock, pressure, wind, salt spray, sand, and dust? Have the ranges and extreme conditions been specified and properly addressed in design? Have the proper environmental profiles been addressed?

9.3 Is the design compatible with air and water quality standards?

9.4 Have provisions been made to specify and control noise, illumination, temperature, and humidity in areas where personnel are required to perform operating and maintenance tasks?

10.0 Facility Requirements

10.1 Have facility requirements (space, volume, capital equipment, utilities, etc.) necessary for system operation been defined?

10.2 Have facility requirements (space, volume, capital equipment, utilities, etc.) necessary for system maintenance at each level been defined?

10.3 Have operational and maintenance facility requirements been minimized to the greatest extent possible?

10.4 Have environmental system requirements (e.g., temperature, humidity, and dust control) associated with operational and maintenance facilities been identified?

10.5 Have storage or shelf-space requirements for spare/repair parts been defined?

10.6 Have storage environments been defined?

10.7 Are the designated facility and storage requirements compatible with the supportability analysis and human-factors data?

11.0 Fasteners

11.1 Are quick-release fasteners used on doors and access panels?

11.2 Is the total number of fasteners minimized?

11.3 Is the number of different types of fasteners held to a minimum? This relates to standardization.

11.4 Have fasteners been selected based on the requirement for standard tools rather than special tools?

12.0 Handling

12.1 For heavy items, are hoist lugs (lifting eyes) or base-fitting provisions for forklift-truck application incorporated? Hoist lugs should be provided on all items weighing more than 150 lb.

12.2 Are hoist and base-lifting points identified relative to lifting capacity?

12.3 Are weight labels provided?

12.4 Are packages, units, components, or other items weighing over more than 10 lb provided with handles? Are the proper-sized handles used, and are they located in the right positions? Are the handles optimally located from the weight-distribution standpoint? Handles should be located over the centers of gravity.

12.5 Are packages, units, or other items weighing more than 40 lb provided with two handles (for a two-person carrying capability)?

12.6 Can normal packing materials be used for shipping? If not, are special containers, cases, or covers provided to protect component-vulnerable areas from damage during handling?

13.0 Human Factors

13.1 Has a system analysis been accomplished to verify optimum human–machine interfaces? Are automated and manual functions adequately identified?

13.2 Are the identified automated/manual functions consistent with the results of the overall system-level functional analysis?

13.3 Have operational sequence diagrams (OSDs) been prepared where appropriate?

13.4 Has a detailed *operator* task analysis been accomplished to verify task sequence, task complexities, personnel skills, and so on?

13.5 Has a detailed *maintenance* task analysis been accomplished to verify maintenance task sequences, task complexities, personnel skills, and so on?

13.6 Is the detailed maintenance task analysis compatible with reliability data, maintainability data, and supportability analysis (SA) data?

13.7 Are the detailed operator and maintenance task analyses compatible with system/product operating and maintenance procedures (e.g., task sequences, depth of explanatory material based on task complexity)?

13.8 For human-interface functions, is the system/product design optimum in considering anthropometric factors, human sensory factors, psychological factors, and physiological factors? For manual tasks, does the design reflect "ease of operation" by low-skilled personnel? Is the design such that potential human error rates are minimized?

13.9 Has a detailed training plan for operator and maintenance personnel been prepared? Have training facility, equipment, material, software, and data requirements been identified?

13.10 Is the human-factors effort compatible with safety and security engineering requirements?

13.11 Has an approach been established for personnel test and evaluation?

14.0 Interchangeability

14.1 Are equipment, modules, and/or components that perform similar operations electrically, functionally, and physically interchangeable?

14.2 Can replacements of like items be made without adjustments and/or alignments?

15.0 Maintainability

15.1 Is the system/product maintainable in terms of troubleshooting and diagnostic provisions, accessibility, ease of replacement, handling capabilities, accuracy of test and verification, and economics in the performance of

maintenance (corrective and preventive)? Actually, many of the other items in this checklist may be appropriately included under maintainability, depending on the organization involved in the design.

15.2 Have maintainability requirements for the system/equipment been adequately defined? Are they compatible with system performance, reliability, supportability, and effectiveness factors?

15.3 Have maintainability requirements been allocated to the appropriate level (e.g., MTBM, MDT, MLH/OH, $\overline{M}$ct, $\overline{M}$pt, $/MA to the unit assembly, subassembly, and/or other appropriate component of the system)? For an explanation of these terms, please refer to chapter 3.

15.4 Have anticipated system/product corrective and preventive maintenance requirements been identified through a detailed maintenance engineering analysis? Have the proper trade-off studies been conducted to attain the proper balance between corrective and preventive maintenance? Too much preventive maintenance can be costly and can significantly impact corrective maintenance requirements. Are the results compatible with supportability analysis (SA) data?

15.5 Has a level-of-repair analysis (LORA) been completed? Are the results consistent with the maintenance concept and the supportability analysis (SA)?

15.6 Have maintainability predictions been accomplished to assess the design in terms of the specified requirements? Do the predictions indicate compliance with the requirements?

15.7 Have maintainability demonstrations been conducted? Do the results indicate compliance with the requirements? Are these requirements included in the Test and Evaluation Master Plan (TEMP)?

16.0 Mobility

16.1 Can the equipment/component be easily transported? Moved from one location to another?

16.2 Can the system component be moved utilizing common and standard support/handling equipment? The use of special handling equipment should be avoided.

17.0 Operability

17.1 Is the system designed for ease of operation?

17.2 Can the system be operated effectively by individuals with basic skills and with a minimum of special training?

17.3 Can system operation be accomplished with a minimum of error?

18.0 Packaging and Mounting

18.1 Is the packaging design attractive from the standpoint of consumer appeal (e.g., color, shape, size)?

18.2 Is functional packaging incorporated to the maximum extent possible? Interaction effects between packages should be minimized. It should be possible to limit maintenance to the removal of one module (the one containing the failed part) when a failure occurs and not require the removal of two, three, or four modules in order to resolve the problem.

18.3 Is the packaging design compatible with level-of-repair analysis decisions? Repairable items are designed to include maintenance provisions such as test points, accessibility, and plug-in components. Items classified as "discard at failure" should be encapsulated and relatively low in cost. Maintenance provisions for a disposable module are not required.

18.4 Are disposable modules incorporated to the maximum extent practical? It is highly desirable to reduce overall support through a no-maintenance-design concept as long as the items being discarded are relatively high in reliability and low in cost.

18.5 Are plug-in modules and components utilized to the maximum extent possible (unless the use of plug-in components significantly degrades the equipment reliability)?

18.6 Are accesses between modules adequate to allow for hand grasping?

18.7 Are modules and components mounted so that the removal of any single item for maintenance will not require the removal of other items? Component stacking should be avoided where possible.

18.8 In areas where module stacking is necessary because of limited space, are the modules mounted in such a way that access priority has been assigned in accordance with the predicted removal and replacement frequency? Items that require frequent maintenance should be more accessible.

18.9 Are modules and components, not of a plug-in variety, mounted with four fasteners or fewer? Modules should be securely mounted, but the number of fasteners should be held to a minimum.

18.10 Are shock-mounting provisions incorporated where shock and vibration requirements are excessive?

18.11 Are provisions incorporated to preclude installation of the wrong module?

18.12 Are plug-in modules and components removable without the use of tools? If tools are required, they should be of the standard variety.

18.13 Are guides (slides or pins) provided to facilitate module installation?

18.14 Are modules and components labeled?

18.15 Are module and component labels located on top or immediately adjacent to the items and in plain sight?

18.16 Are the labels permanently affixed and unlikely to come off during a maintenance action or as a result of environment? Is the information on the label adequate? Disposable modules should be so labeled. In equipment racks, are the heavier items mounted at the bottom of the rack? Unit weight should decrease with the increase in installation height.

18.17 Are operator panels optimally positioned? For personnel in the standing position, panels should be located between 40 and 70 in. above the floor. Critical or precise controls should be between 48 and 64 in. above the floor. For personnel in the sitting position, panels should be located 30 in. above the floor.

18.18 Are drawers in equipment racks mounted on roll-out slides?

19.0 Panel Displays and Controls

19.1 Are controls standardized?

19.2 Are controls sequentially positioned?

19.3 Is control spacing adequate?

19.4 Is control labeling adequate?

19.5 Have the proper control/display relationships been incorporated (based on good human-factors criteria)?

19.6 Are the proper types of panel switches used?

19.7 Is the control panel lighting adequate?

19.8 Are the controls placed according to frequency and/or criticality of use?

20.0 Personnel and Training

20.1 Have operational and maintenance personnel requirements (quantity and skill levels) been defined?

20.2 Are operational and maintenance personnel requirements minimized to the greatest extent possible?

20.3 Are operational and maintenance personnel requirements compatible with supportability analysis and with human-factors data? Personnel quantities and skill levels should "track" both sources.

20.4 Are the planned personnel skill levels at each location compatible with the complexity of the operational and maintenance tasks specified?

20.5 Has maximum consideration been given to the use of existing personnel skills for new equipment?

20.6 Have personnel attrition rates been established?

20.7 Have personnel effectiveness factors been determined (actual time that work is accomplished per the total time allowed for work accomplishment)?

20.8 Have operational and maintenance training requirements been specified? This includes consideration of both initial training and replenishment training throughout the life cycle.

20.9 Have specific training programs been planned? The type of training, frequency of training, duration of training, and student entry requirements should be identified.

20.10 Are the planned training programs compatible with the personnel skill-level requirements specified for the performance of operational and maintenance tasks?

20.11 Have training equipment requirements been defined? Have the applicable training equipment been acquired?

20.12 Have maintenance provisions for training equipment been planned?

20.13 Have training data requirements been defined?

20.14 Are the planned operating and maintenance procedures (designated for support of the system throughout its life cycle) utilized to the maximum extent possible in the training program(s)?

21.0 Producibility

21.1 Does the design lend itself to economic production? Can simplified fabrication and assembly techniques be employed?

21.2 Has the design stabilized (minimum change)? If not, are changes properly controlled through good configuration management methods?

21.3 Is the design such that rework requirements are minimized? Are spoilage factors held to a minimum?

21.4 Has the design been verified through prototype testing, environmental qualification, reliability qualification, maintainability demonstration, and the like?

21.5 Is the design such that many models of the same item can be produced with identical results? Are fabrication steps, manufacturing processes, and assembly methods adequately controlled through good quality assurance procedures?

21.6 Has adequate consideration been given to the application of just-in-time (JIT), Taguchi, material requirements planning (MRP), enterprise resource planning (ERP), and related methods in the production process?

21.7 Are production drawings, computer-aided design (CAD), computer-aided manufacturing (CAM), computer-aided support (CAS) data, materials lists, and so on, adequate for production needs?

21.8 Can currently available facilities, standard tools, and existing personnel be used for fabrication, assembly, manufacturing and test operations?

21.9 Is the design such that automated manufacturing processes (e.g., CAM, numerical control techniques) can be applied for high-volume repetitive functions?

21.10 Is the design definition such that two or more suppliers can produce the system/product from a given set of data with identical results?

22.0 Reconfigurability

22.1 Is the design configuration such that it can be readily upgraded for improved capability?

22.2 Have preplanned product improvements been considered in the initial design of the system?

22.3 Can modifications for performance enhancement be incorporated at minimum cost?

23.0 Reliability

23.1 Is the design simple? Have the number of component parts been kept to a minimum?

23.2 Are standard high-reliability parts being utilized?

23.3 Are item failure rates known? Has the mean life been determined?

23.4 Have parts been selected to meet reliability requirements?

23.5 Have parts with excessive failure rates been identified (unreliable parts)?

23.6 Have adequate derating factors been established and adhered to where appropriate?

23.7 Have the shelf life and wear-out characteristics of parts been determined?

23.8 Have all critical-useful-life items been eliminated from the design? If not, have they been identified with inspection/replacement requirements specified? Has a critical-useful-life analysis been accomplished?

23.9 Have critical parts that require special procurement methods, testing, and handling provisions been identified?

23.10 Has the need for the selection of "matching" parts been eliminated?

23.11 Have fail-safe provisions been incorporated where possible (protection against secondary failures resulting from primary failures)?

23.12 Has the use of "adjustable" components been minimized?

23.13 Have safety factors and safety margins been used in the application of parts?

23.14 Have component failure modes and effects been identified? Has a failure mode and effects analysis (FMEA), a failure mode, effects, and criticality analysis (FMECA), and/or a fault-tree analysis (FTA) been accomplished?

23.15 Has a stress-strength analysis been accomplished?

23.16 Have cooling provisions been incorporated in design "hot spot" areas? Is cooling directed toward the most critical items?

23.17 Has redundancy been incorporated in the design where needed to meet specified reliability requirements?

23.18 Are the best available methods for reducing the adverse effects of operational and maintenance environments on critical components being incorporated?

23.19 Have the risks associated with critical-item failures been identified and accepted? Is corrective action in design being taken?

23.20 Have reliability requirements for spares and repair parts been considered?

23.21 Have reliability predictions been accomplished? Have reliability testing requirements been defined? Test requirements in design? Test requirements in production/construction? Have they been covered in the Test and Evaluation Master Plan (TEMP)?

23.22 Has a reliability failure analysis and corrective action capability been installed?

24.0 Safety

24.1 Has an integrated safety engineering plan been prepared and implemented?

24.2 Has a hazard analysis been accomplished to identify potential hazardous conditions? Is the hazard analysis compatible with the reliability FMECA/FMEA and FTA (where applicable)?

24.3 Have system/product hazards related to heat, cold, thermal change, barometric change, humidity change, shock, vibration, light, mold, bacteria, corrosion, rodents, fungi, odors, chemicals, oils, greases, handling and transportation, and so on, been eliminated?

24.4 Have fail-safe provisions been incorporated in the design?

24.5 Have protruding devices been eliminated, or are they suitably protected?

24.6 Have provisions been incorporated for protection against high voltages? Are all external metal parts adequately grounded?

24.7 Are sharp metal edges, access openings, and corners protected with rubber, fillets, fiber, or plastic coating?

24.8 Are electrical circuit interlocks employed?

24.9 Are standoffs or handles provided to protect system components from damage during the performance of shop maintenance?

24.10 Are tools that are used near high-voltage areas adequately insulated at the handle or at other parts of the tool that maintenance personnel are likely to touch?

24.11 Are the environments such that personnel safety is ensured? Are noise levels with a safe range? Is illumination adequate? Is the air clean? Are the temperatures at a proper level? Are the requirements of the Occupational Health and Safety Administration (OSHA) being maintained?

24.12 Has the proper protective clothing been identified for areas where the environment could be detrimental to human safety? Radiation, intense cold or heat, gas, loud noise, and so on, are examples of detrimental factors.

24.13 Are safety equipment requirements identified for areas where ordinance devices (and the like) are activated?

25.0 Selection of Parts/Materials

25.1 Have appropriate standards been consulted for the selection of components and materials?

25.2 Have all component parts and materials selected for the design been adequately evaluated prior to their procurement and application? Evaluation should consider performance parameters, reliability, maintainability, supportability, human factors, quality, and cost.

25.3 Have supplier sources for component-part and material procurement been established?

25.4 Are the established supplier sources reliable in terms of quality level, ability to deliver on time, and willingness to accept component-warranty provisions? There is an ongoing concern in regard to control specifications, process variations, stresses, tolerances, item interchangeability, and so on.

25.5 Have alternative supplier sources been identified for use in the event that the prime source fails to deliver?

26.0 Servicing and Lubrication

26.1 Have servicing requirements been held to a minimum?

26.2 Where servicing is indicated, are the specific requirements identified?

26.3 Are procurement sources for servicing materials known?

26.4 Are servicing points accessible?

26.5 Have personnel and equipment requirements for servicing been identified? This includes handling equipment, vehicles, carts, and so on.

26.6 Does the design include servicing indicators?

27.0 Societal Requirements

27.1 Does the system/product satisfy societal needs?

27.2 Have the societal effects of introducing the system/product into the inventory been evaluated (to determine the impact of system operation and support on community life)?

27.3 Have all adverse societal effects caused by the introduction, operation, and support of the system/product been minimized, if not eliminated?

28.0 Software

28.1 Have all system software requirements for operating and maintenance functions been identified? Have these requirements been developed through the system-level functional analysis (i.e., is there traceability indicated)?

28.2 Is the software complete in terms of scope and depth of coverage?

28.3 Is the software compatible relative to the equipment with which it interfaces? Is operating software compatible with maintenance software? With other elements of the system?

28.4 Are the language requirements for operating software and maintenance software compatible?

28.5 Is all software adequately covered through good documentation (i.e., logic functional flows and coded programs)?

28.6 Has the software been adequately tested and verified for accuracy (performance), reliability, and maintainability?

29.0 Standardization

29.1 Are standard commercial off-the shelf (COTS) components and parts incorporated in the design to the maximum extent possible (except for items not compatible with effectiveness factors)? Maximum standardization is desirable.

29.2 Are the same items and/or parts used in similar applications?

29.3 Are identifying equipment labels and nomenclature assignments standardized to the maximum extent possible?

29.4 Are equipment-control-panel positions and layouts (from panel to panel) the same or similar when a number of panels are incorporated and provide comparable functions?

30.0 Storage

30.1 Can the equipment be stored for extended periods of time without excessive degradation (beyond specification limits)?

30.2 Have scheduled maintenance requirements for stored equipment been defined?

30.3 Have scheduled maintenance requirements for stored equipment been eliminated or minimized?

30.4 Have the required maintenance resources necessary to service stored equipment been identified?

30.5 Have storage environments been defined?

31.0 Supportability

31.1 Have spare/repair part requirements been minimized to the greatest extent possible? Is the number of different part types used throughout the design minimized?

31.2 Are the types and quantity of spare/repair parts compatible with the system maintenance concept, the supportability analysis (SA), and level-of-repair analysis data?

31.3 Are the types and quantity of spare/repair parts designated for a given location appropriate for the estimated demand at that location? Too many or too few spares can be costly.

31.4 Have the distribution channels and inventory points for spare/repair parts been established?

31.5 Are spare/repair part provisioning factors (e.g., replacement frequencies) directly traceable to reliability and maintainability predictions?

31.6 Are the specified logistics pipeline times compatible with effective supply support? Long pipeline times place a tremendous burden on logistic support.

31.7 Have spare/repair parts been identified and provisioned for preoperational support activities (e.g., interim producer or supplier support, test programs)?

31.8 Have test and acceptance procedures been developed for spare/repair parts? Spare/repair parts should be processed, produced, and accepted on a similar basis as their equivalent components in the prime equipment.

31.9 Have the consequences (risks) of stock-out been defined in terms of effect on mission requirements and cost?

31.10 Has an inventory safety stock level been defined?

31.11 Has a provisioning or procurement cycle been defined (procurement or order frequency)? Have economic order quantity (EOQ) factors been determined?

31.12 Has a supply-availability requirement been established (the probability of having a spare available when required)?

31.13 Have the test and support equipment requirements been defined for each level of maintenance?

31.14 Have standard test and support equipment items been selected? Newly designed equipment should not be necessary unless standard equipment is unavailable.

31.15 Are the selected test and support equipment items compatible with the prime equipment? Does the test equipment do the job?

31.16 Are the test and support equipment requirements compatible with maintenance concept, supportability analysis (SA), and level-of-repair analysis data?

31.17 Have test and support equipment requirements (in terms of both variety and quantity) been minimized to the greatest extent possible?

31.18 Are the reliability and maintainability features in the test and support equipment compatible with those equivalent features in the prime equipment? It is not practical to select an item of support equipment that is not as reliable as the item it supports.

31.19 Have logistic support requirements for the selected test and support equipment been defined? This includes maintenance tasks, calibration equipment, spare/repair parts, personnel and training, data, and facilities.

31.20 Is the test and support equipment selection process based on cost-effectiveness considerations (i.e., life-cycle cost)?

31.21 Have test and maintenance software requirements been adequately defined?

31.22 Have operational and maintenance personnel requirements (quantity and skill levels) been defined?

31.23 Are operational and maintenance personnel requirements minimized to the greatest extent possible?

31.24 Are operational and maintenance personnel requirements compatible with supportability analysis (SA) and with human-factors data? Personnel quantities and skill levels should track both sources.

31.25 Are the planned personnel skill levels at each location compatible with the complexity of the operational and maintenance tasks specified?

31.26 Has maximum consideration been given to the use of existing personnel skills for the new system?

31.27 Have personnel attrition rates been established?

31.28 Have personnel effectiveness factors been determined (actual time that work is accomplished per the total time allowed for work accomplishment)?

31.29 Have operational and maintenance training requirements been specified? This includes consideration of both initial training and replenishment training throughout the life cycle.

31.30 Have specific training programs been planned? The type of training, frequency of training, duration of training, and student entry requirements should be identified.

31.31 Are the planned training programs compatible with the personnel skill-level requirements specified for the performance of operational and maintenance tasks?

31.32 Have training equipment requirements been defined? Has the needed training equipment be procured?

31.33 Have maintenance provisions for training equipment been planned?

31.34 Have training data requirements been defined?

31.35 Are the planned operating and maintenance procedures (designated for support of the system throughout its life cycle) utilized to the maximum extent possible in the training program(s)?

32.0 Support Equipment Requirements

Refer to Questions 31.13 through 31.21, Category 31.0, "Supportability," for coverage of test and support equipment.

33.0 Survivability

33.1 Has an integrated survivability engineering plan been prepared and implemented?

33.2 Have survivability measures been established, and are they appropriately integrated with other system TPMs?

33.3 Has a test and evaluation approach been defined for the verification of system survivability? Is this covered in the Test and Evaluation Master Plan (TEMP)?

34.0 Testability

34.1 Have self-test provisions been incorporated where appropriate?

34.2 Is reliability degradation due to the incorporation of built-in test (BIT) minimized? The BIT capability should not significantly impact the reliability of the overall system.

34.3 Is the extent or depth of self-testing compatible with the level-of-repair analysis?

34.4 Are self-test provisions automatic?

34.5 Have direct fault indicators been provided (a fault light, an audio signal, or a means of determining that a malfunction positively exists)? Are continuous condition monitoring provisions incorporated where appropriate?

34.6 Are test points provided to enable checkout and fault isolation beyond the level of self-test? Test points for fault isolation within an assembly should not be incorporated if the assembly is to be discarded at failure. Test point provisions must be compatible with the level of repair analysis.

34.7 Are test points accessible? Accessibility should be compatible with the extent of maintenance performed. Test points on the operator's front panel are not required for a depot maintenance action.

34.8 Are test points functionally and conveniently grouped to allow for sequential testing (following a signal flow), testing of similar functions, or frequency of use when access is limited?

34.9 Are test points provided for a direct test of all replaceable items?

34.10 Are test points adequately labeled? Each test point should be identified with a unique number, and the proper signal or expected measured output should be specified on a label located adjacent to the test point.

34.11 Are test points adequately illuminated to allow the technician to see the test point number and labeled signal value?

34.12 Can every component malfunction (degradation beyond specification tolerance limits) that could possibly occur be detected through a no-go indication at the system level? Are false alarm rates minimized? This is a measure of test thoroughness.

34.13 Will the prescribed maintenance software provide adequate diagnostic information?

35.0 Transportability

35.1 Have transportation and handling requirements been defined?

35.2 Have transportation requirements been considered in the equipment design? This includes consideration of temperature ranges, vibration and shock, humidity, and so on. Has the possibility of equipment degradation been minimized if transported by air, ground vehicle, ship, or rail?

35.3 Can the equipment be easily disassembled, packed, transported from one location to another, reassembled, and operated with a minimum of performance and reliability degradation?

35.4 Have container requirements been defined?

35.5 Have the requirements for ground handling equipment been defined?

35.6 Was the selection of handling equipment based on cost-effectiveness considerations?

36.0 Quality

36.1 Has a total quality management (TQM) plan been prepared and implemented? Does it include coverage of customer, contractor (producer), and supplier activities and interfaces?

36.2 Are formal quality (i.e., TQM) training programs being conducted within the customer/contractor/supplier organization?

36.3 Are statistical process control (SPC) methods/techniques being implemented where appropriate?

36.4 Are quality control requirements specified and imposed on all suppliers?

The preceding questions are representative of what may be considered in conducting a program/design review. They should not be considered as being all-inclusive by any means. In fact, it is appropriate for the reviewer to develop a list covering applicable issues tailored to the program in question.