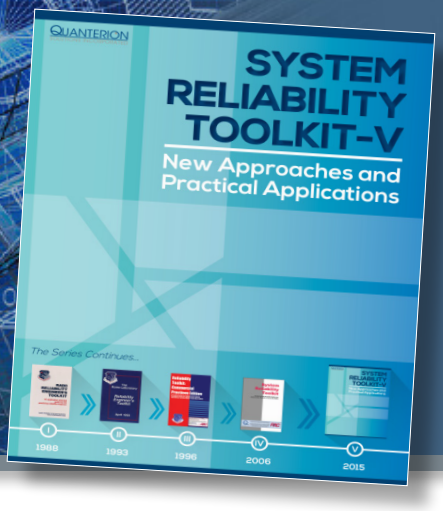
# Lessons in System Reliability

FROM THE QUANTERION ***SYSTEM RELIABILITY TOOLKIT-V***




*The important topics included in this short publication are shared from the popular Quanterion Solutions' 900+ page System Reliability Toolkit-V. Please give us a call if you need help in any reliability engineering need (315-732-0097).*

*This edition includes one Toolkit topic, which is Topic 2.1: The Systems Engineering Process.*

## Topic 2.1: The Systems Engineering Process

This section defines the systems engineering (SE) tasks that are generally applicable throughout the system life cycle of any program, involving new development, upgrade, modification, resolution of deficiencies, or development and exploitation of technology.

Following is an outline of the major and supporting tasks of the systems engineering process. Figure 2.1-1 illustrates a generic systems engineering process (SEP) from a flow perspective.

- Systems Engineering Planning and Implementation
- Systems Engineering Input
  - Technical objectives
- Systems Engineering Process Requirements
  - Requirements analysis
  - Functional analysis/allocation
  - Synthesis
  - Systems analysis and control
- Trade-off studies
- System/cost-effectiveness analysis
- Risk management
- Configuration management
- Interface management
- Data management
- Integrated master plan (IMP)
- Technical performance measurement (TPM)
- Technical reviews
- Systems Engineering Output
  - Specifications and baselines
  - Life-cycle support data

A basic system life-cycle model is shown in Figure 2.1-2. While application of the system engineering process is life-cycle oriented (i.e., the process is applicable in each and every phase of the system life cycle), the critical steps to ensure that design for reliability objectives are realized are indicated by the shaded area in the figure.

The performing activity employs the SEP of requirements analysis, functional analysis/allocation, synthesis, and systems analysis and control in progressive levels of detail throughout the effort to achieve program objectives and to define requirements, designs and solutions for

the system life cycle. This concept is shown in Figure 2.1-3. Figure 2.1-4 illustrates the classic representation of SEP requirements.

**Systems Engineering Process Inputs**

As shown in Figure 2.1-4, the process input includes information necessary to support continued technical effort (includes results from technology validation and item verification) as well as initiation of a new phase of technical effort (includes new or updated customer needs, technology base data, outputs from a previous phase, and program constraints). The performing activity notifies the chief engineer that technical input information is needed, why it is needed, and

**Figure 2.1-1. General Systems Engineering Process (SEP)**

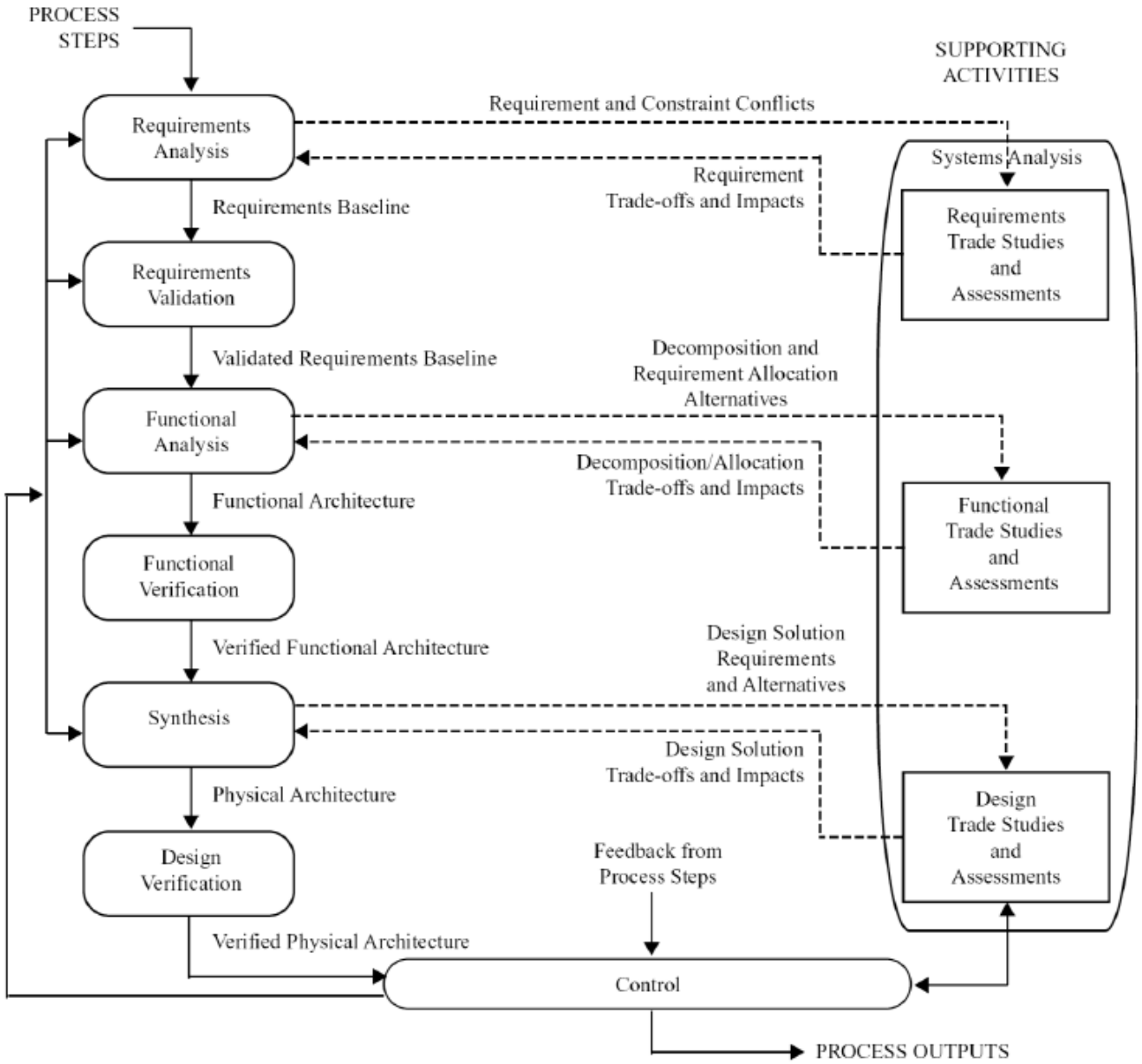


**Figure 2.1-2. The System Life Cycle - Shaded Area is Pre-Systems Acquisition**

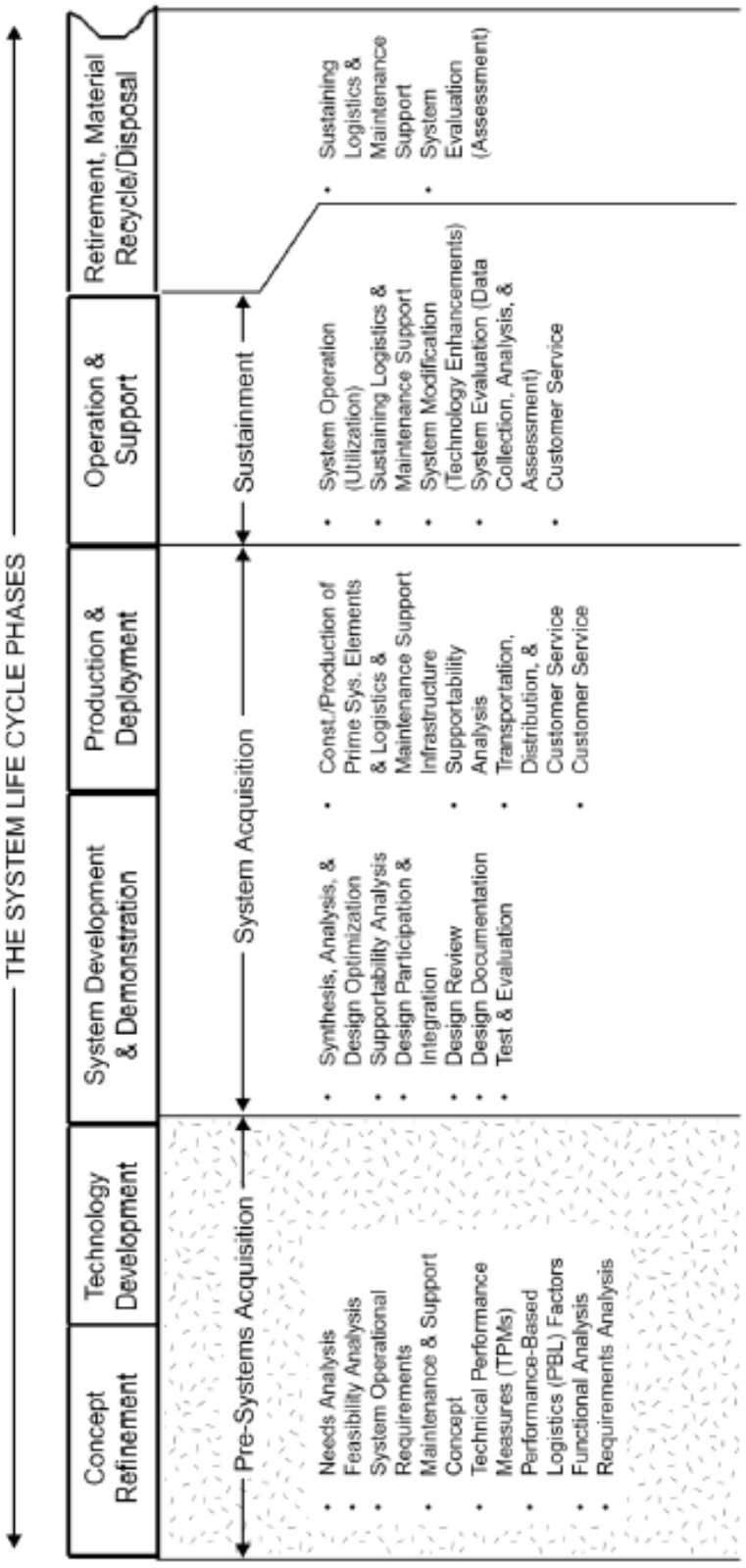


Figure 2.1-3. Systems Engineering Effort in the System Life Cycle

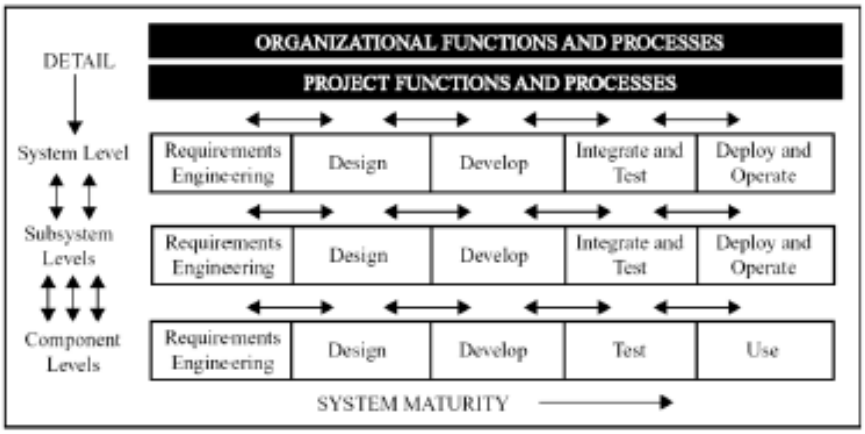
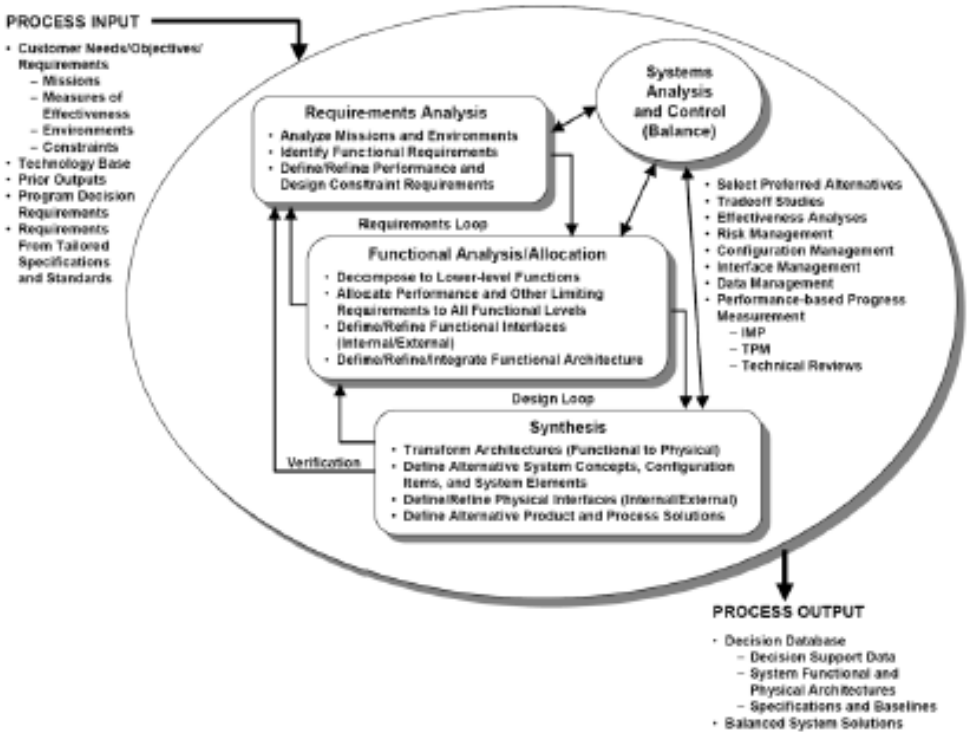



Figure 2.1-4. The Systems Engineering Process Requirements




when it is needed. The chief engineer will inform the performing activity what information can and cannot be provided. If the information will not be provided, then it must be generated in the defined task using documented research, analysis, and assumptions.

The performing activity analyzes customer needs, objectives, and requirements in the context of customer missions, environments, and identified system characteristics to determine functional and performance requirements for each primary system function. Prior analyses are reviewed

and updated to refine mission and environment definitions to support system definition. Requirements analysis is conducted iteratively with functional analysis to develop requirements that depend on additional system definition (e.g., other system items, performance requirements for identified functions) and verify that people, product, and process solutions (from synthesis) can satisfy customer requirements. In conducting requirements analysis, the performing activity:

- Assists in refining customer objectives and requirements.
- Defines initial performance objectives and refines them into requirements.
- Identifies and defines constraints that limit solutions (e.g., missions and environments or adverse impacts on natural and human environments).
- Defines functional and performance requirements based on customer provided measures of effectiveness (MOEs).

When MOEs are not provided at the level of detail needed, the performing activity develops and uses a set of MOEs relating to customer missions, environments, needs, requirements and objectives, and design constraints.

Functional requirements, identified in the requirements analysis, and process inputs are used as the top-level functions for functional analysis. Performance requirements are developed interactively across all identified functions based on system lifecycle factors and characterized in terms of the degree of certainty of the estimate, the degree of criticality to system success, and relationship to other requirements.

**Functional Analysis/Allocation**

The performing activity defines and integrates a functional architecture to the depth needed to support synthesis of solutions for people, products, and processes and risk management. Functional analysis/allocation is conducted iteratively:

- To define successively lower-level functions required to satisfy higher-level functional requirements and to define alternative sets of functional requirements.
- With requirements analysis to define mission- and environment-driven performance parameters and to determine that higher-level requirements are satisfied.
- To flow down performance requirements and design constraints.
- With synthesis to define and refine feasible alternatives that meet requirements and to place derived requirements into the functional architecture.

**Synthesis**

The performing activity defines and designs solutions for each logical set of functional and performance requirements in the functional architecture and integrates them as a physical architecture. The performing activity conducts synthesis iteratively with functional analysis/allocation to define a complete set of functional and performance requirements necessary for the level of design output required. Requirements analysis is used to verify that solution outputs can satisfy customer input requirements. In first defining the solution, the performing activity:

- Determines the completeness of functional and performance requirements for the design and identifies derived requirements needed for completeness in terms of function and performance.
- Defines internal and external physical interfaces including required function and performance and ensures that requirements are integrated and verifiable across interfaces.

- Identifies critical parameters, then analyzes parameter variability and solution sensitivity to the variability.
- Defines people, product, and processes alternatives interactively (including the concepts, techniques, and procedural data applicable to each of the primary system functions) as well as required allowances for tolerances and variabilities for those alternatives.
- Defines system, configuration item (CI), and system element solutions to a level of detail that enables verification that required accomplishments have been met.
- Translates the architecture into a work breakdown structure (WBS), specification tree, specifications, and configuration baselines.

**Systems Analysis and Control**

The performing activity measures progress, evaluates alternatives, selects preferred alternatives, and documents data and decisions made. Systems analyses are conducted including trade-off studies, effectiveness analyses and assessments, and design analyses to determine progress in satisfying technical requirements and program objectives and to provide a rigorous quantitative basis for performance, functional, and design requirements. Control mechanisms include risk management, configuration management, data management, and performance-based progress measurement including the IMP, TPM, and technical reviews. The performing activity implements systems analysis and control to ensure that the following areas are covered thoroughly.

- Decisions on solution alternatives are made only after evaluating the impact on system effectiveness, life-cycle resources, risk, and customer requirements. The performing activity identifies those alternatives that will provide improved system effectiveness or costs when compared with those based on program requirements.
- Technical decisions and system-unique specification requirements are based on SE outputs and documented results of decisions.
- Traceability from process inputs to outputs is maintained, including changes in requirements.
- Schedules for the development and delivery of products and processes are mutually supportive.
- Technical disciplines and disciplinary efforts are integrated into the SE effort.
- Impacts of customer requirements on resulting functional and performance requirements are examined for validity, consistency, desirability, and attainability with respect to technology availability, physical and human resources, human performance capabilities, life-cycle costs, schedule, risk, applicable statutes, designated hazardous material lists, and other identified constraints. This examination needs to either confirm existing requirements or determine that more appropriate requirements need to be defined for the system.
- Product and process design requirements are directly traceable to the functional and performance requirements that the design requirements were designed to fulfill and vice versa.

Figure 2.1-5 provides a conceptual look at a system analysis process.

**Systems Engineering Process Outputs**

Outputs of the SE effort vary by and depend on the acquisition phase. The performing activity develops and implements a decision database that handles the following tasks:

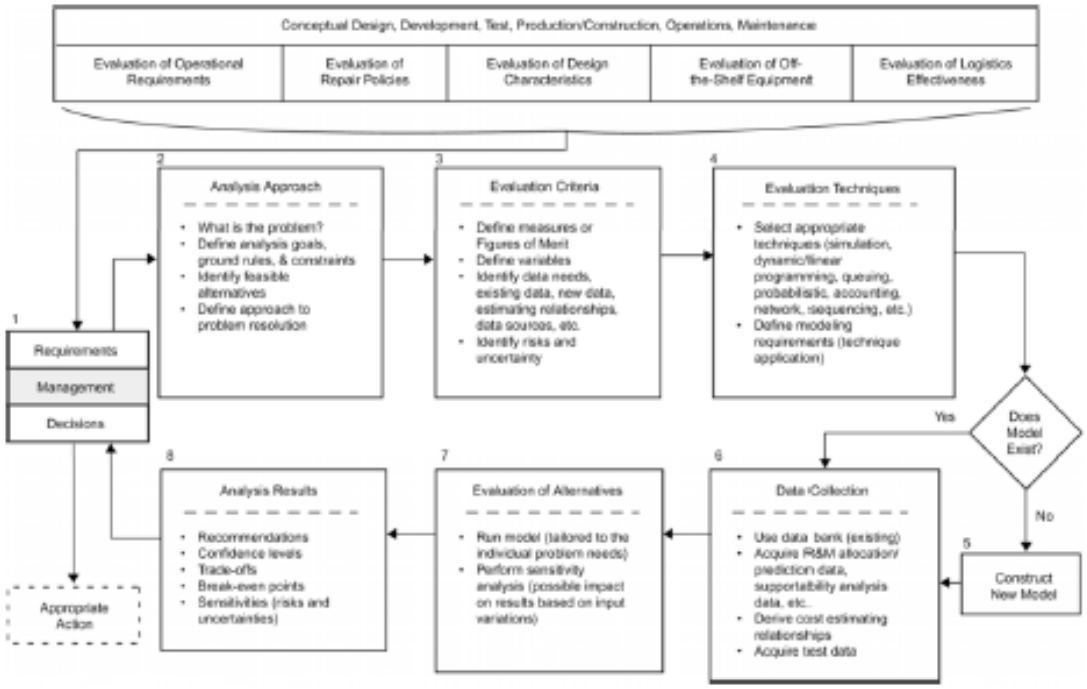
- Documents and organizes data used and generated by the SE effort.
- Provides an audit trail of results and rationale from identified needs to verified solutions for traceability of requirements, designs, decisions, and solutions.

The performing activity generates required system and CI-unique documentation. General criteria are necessary in the following areas:

- Documentation used to establish configuration baselines (functional, allocated, product) is developed progressively.
- Specifications are formalized to establish configuration baselines commensurate with the program effort.
- Configuration baselines are documented, controlled, and audited in accordance with program configuration management practices.
- Essential requirements for processes are included in item specifications.
- Specification requirements need to be verifiable. Traceability to the verification criteria and methods is maintained.
- The performing activity presents specifications for approval only when:
  - The cost, schedule, and performance risks associated with the item and its processes have been determined and the risk levels are acceptable.
  - Item costs have been determined and those costs satisfy established design-to-cost targets or other prescribed affordability limits.
  - Completeness and design attainability have been confirmed.
- System functional and CI development specifications need to be performance-based.

The performing activity identifies, annotates, and tracks

**Figure 2.1-5: A Systems Analysis Approach**



those elements in the decision database necessary for life-cycle management of the system to:

- Product performance monitoring, analysis, problem identification, and corrective action recommendations.
- Life cycle supportability analysis to identify operational and support resource requirements, to include any changes in requirements due to changes in the user community, missions, operational tempo, and operational strategy.
- Identification of drivers of systems readiness degraders and excessive Total Ownership Costs (TOC) contributors. Analysis of alternative courses of actions and recommended actions to improve material readiness and/or reduce TOC.
- Provide product support engineering services systems to user organizations.

**For More Information:**

1. Manary, J., "A Practical Framework for Acquirers and Providers of Systems Engineering Services", Reliability Analysis Center, April 2004.

2. Blanchard, B.S. and Langford, J.W., "Supportability Toolkit", Reliability Analysis Center, February 2005 2000, ISBN 0073655783.

*This tech brief is the continuation of a monthly series from Quanterion Solutions' System Reliability Toolkit-V.*

*The next article in the series is Topic 2.4: Overview of Software Reliability, which explores the relationship between these two categories of reliability engineering.*

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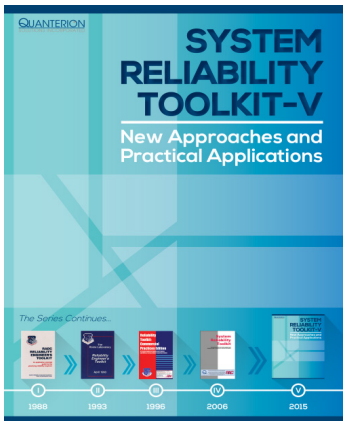


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