<u>National Compact Stellarator Experiment</u>

NCSX

RELIABILITY, AVAILABILITY, AND MAINTAINABILITY PLAN

NCSX-PLAN-RAM-00

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NCSX RELIABILITY, AVAILABILITY, AND MAINTAINABILITY PLAN

RECORD OF REVISIONS

Revision	Date	Originator	Description of Change
0	2/13/04	Simmons	Initial issue.

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NCSX RELIABILITY, AVAILABILITY, AND MAINTAINABILITY PLAN

1 BACKGROUND

1.1 Overview

Experience has demonstrated that the design and commissioning of complex systems and devices with major technological advances will invariability have significant reliability deficiencies that could not be foreseen in the early design stages. The National Compact Stellarator Experiment is certainly one of the more complex and technologically advanced fusion concepts under development today. The primary objective of the NCSX Reliability, Availability, and Maintainability (RAM) program is to instill the systematic design disciplines to minimize or perhaps eliminate reliability deficiencies.

From a reliability engineering perspective, the NCSX design incorporates all the classic hardware and system reliability risks associated with magnetic stresses and forces, electrical stresses, thermal stresses, vibration, moisture, and friction. The primary NCSX design concern for reliability and maintainability is the close tolerances and design margins of major stellarator core components. The RAM design designs for these components are critical considerations for NCSX success. Further, it can be expected that, should significant NCSX reliability problems emerge, dedicated management attention and significant resources will be required to correct the problem. Hence the desire to be proactive in the design to mitigate and/or eliminate potential RAM design problems is of paramount importance as the design progresses.

1.2 Applicable Documents

This RAM Plan draws on the documents listed below. Documents referenced are the latest issues of:

- Project Execution Plan (NCSX-PLAN-PEP)
- Systems Engineering Management Plan (NCSX-PLAN-SEMP)
- Quality Assurance Plan (NCSX-PLAN-QAP)
- Risk Management Plan (NCSX-PLAN-RMP)
- Configuration Management Plan (NCSX-PLAN-CMP)
- Interface Control Management Plan (NCSX-PLAN-ICMP)
- PPPL Engineering Procedure ENG-008, “Failure Modes and Effects Analysis”
- NCSX Procedure NCSX-PROC-004, “NCSX Work Planning Process”

1.3 RAM Definitions

1.3.1 Reliability

Reliability is a probability that a NCSX component system will perform its intended mission for a specified interval under specific conditions. Simply stated, it is what fraction of the time the component or system will work. Mathematically, it can be expressed in terms of the Mean Time Between Failures (MTBT) or failures over time and the Mean Time to Repair (MTTR). Qualitatively, it must be demonstrated that component or system designs are robust and utilize components or systems with a proven track record of operational success.

1.3.2 Maintainability

Maintainability is a probability that if prescribed procedures and resources are used, a NCSX component or system will operate in the desired condition, or can be restored to that condition, within a specified time interval. It is the inherent characteristic of a design that determines the amount of maintenance required to retain or restore the component or system to its desired condition; e.g., how quickly can the component or system be fixed. Qualitatively, it must be demonstrated that maintenance procedures and necessary spares will be available when needed.

1.3.3 Availability

Availability is based on the question, "is the NCSX component or system available in a working condition when it is needed." It reflects the readiness of the component or system. Qualitatively, it must be demonstrated that the component or system will be available when needed. A mathematical expression of availability is uptime divided by the sum of uptime and downtime.

1.2.4 Inspectability

Inspectability is the ability or ease of inspecting to determine where the component or system is in its service lifetime. A proactive inspection and preventive maintenance program can thus result in increased reliability, maintainability, and availability.

2 PURPOSE AND REQUIREMENTS

Rather than develop detailed RAM predictive models, the NCSX Project will apply a graded approach that sets out the principles and processes for ensuring the design is developed with due consideration to RAM requirements and that the achievement of these RAM requirements is demonstrated during design reviews. This document lays out the guidelines and processes by which the RAM program is implemented based on consider of risk. This approach is much more qualitative in nature than the classical RAM mathematical analyses.

The NCSX General Requirements Document (NCSX-ASPEC-GRD) implements the overall project for mission reliability, operational availability, shot reliability, and maintainability. These general RAM requirements are then allocated down to the system and subsystem level via the Development Specifications (BSPECS) and further down to the component level via the Product Specifications (CSPEC). The hierarchy of specifications and relationships is described in further detail in the Systems Engineering Management Plan (NCSX-PLAN-SEMP). This RAM Plan compliments other NCSX Plans such as the Quality Assurance Plan (NCSX-PLAN-QAP) and the Configuration Management Plan (NCSX-PLAN-CMP), applicable PPPL Engineering Procedures (e.g., ENG-008, "FEMCA", etc.), and applicable NCSX Procedures (e.g., NCSX-PROC-004, "NCSX Work Planning Process", etc.).

An effective RAM program is complimentary to the risk management approaches taken by the NCSX Project. As outlined in the NCSX Risk Management Plan, risk management is a priority focus of everyone on the project. The Project has taken a proactive position in identifying possible technical, cost, and schedule risk areas and identified risk mitigation strategies. These strategies, when combined with the RAM approaches outlined in this plan will result in a more robust and effective experiment.

Although this plan focuses on RAM processes during the design stages of the Project, RAM considerations are also critical and important during operations and any subsequent modifications to the device. The Configuration Control and Interface Control processes outlined in the Configuration Management Plan (NCSX-PLAN-CMP) and the Interface Control Management Plan (NCSX-PLAN-ICMP respectively and their implementing procedures NCSX-PROC-002, "Configuration Control," and NCSX-PROC-003, "Interface Control," imply the importance of implementing an effective RAM program to ensure a robust design.

3 RESPONSIBILITIES

3.1 Systems Engineering

The NCSX Engineering Manager is responsible for the development and implementation of the NCSX RAM program. The Systems Engineering Support Manager assists him in carrying out this responsibility.

3.2 WBS Managers

WBS Managers are responsible for optimizing designs for reliability and maintainability through systematic evaluation of design options, and for performing Failure Modes, Effects and Criticality Analyses (FEMCAs) for RAM design improvement and verification. They are expected to demonstrate that their designs are robust from a RAM perspective at design reviews. PPPL Engineering Procedure ENG-008, "Failure Modes and Effects Analysis," provides detailed guidance and requirements for performing FEMCAs.

In addition, as part of the design review process, the WBS Manager is expected to demonstrate how RAM considerations were factored into his or her design. The NCSX procedure on work process, NCSX-PROC-004, "NCSX Work Planning Process," includes RAM as one of the design review checklist items.

4 QUALITATIVE CHARACTERISTICS OF THE NCSX RAM PROGRAM

4.1 Reliability

4.1.1 Requirements

The process to a more reliable component or system begins with the establishment and communication of requirements for capability, operational thresholds, and goals in clear and easily understood terms. Several key features are important to remember:

- The requirements must be clear;
- The design requirements should be as simple as possible - simple design requirements lead to components and systems that are less expensive to build, operate, and maintain;
- Opportunity improvements for a design should be identified via a failure modes and effects analysis
- The requirements should be testable (easily verified).
- The requirements should take into consideration the ability to maintain the component or system. They should cover such items as reducing the likelihood of failure, the ability to detect the cause of a failure and effect corrections, and the need for interchangeability of identical multiple items.

Recognizing that NCSX is a first-of-a-kind experimental device, bottoms-up reliability predictions are difficult to perform and have large uncertainties. Therefore, quantitative RAM requirements and apportionments down to lower level systems and components will be few. The GRD identifies several of the specific RAM requirements and actions. For example, the GRD contains specific requirements for:

- Personnel access inside the vacuum vessel;
- Personnel access outside the device for access to components and diagnostics;
- Recovery from every credible failure mode;
- Preventive maintenance;
- Stellarator core disassembly and reassembly;
- Lift provisions; etc.

4.1.2 Design Process

Successful designs utilize robust and proven components and systems that have a successful demonstrated track record. For those components and systems that are approaching state-of art, the reliability of the design can be improved by:

- Establishing design criteria based on historical experience with proven designs. These design criteria are documented in “design to” specifications and manifested in detailed “build to” specifications;

- Performing trade studies to arrive at design concepts with the highest potential design margins;
- Performing sufficient research and development activities to demonstrate that the proposed design is robust, can be easily built, and will satisfy desire performance parameters;
- Making detailed decisions that may adjust requirements, resources, and constraints into the most reliable design.
- Ensuring that interfaces between adjacent systems and components are clearly defined and understood via the Interface Control Management program (NCSX-PLAN-ICMP).
- Ensuring that the full impact of proposed design changes are understood and approved by all impacted WBS managers via the formal change control process (NCSX-PLAN-CMP).

4.2 Maintainability

Maintenance is an important process in achieving high maintainability – both preventative maintenance and corrective maintenance. Maintainability is a design consideration and maintenance is a consequence of that design. Maintainability can be improved by paying proper attention to the following areas:

- Accessibility – Can the component and/or system be easily reached for repair or adjustments? If not, how is the accessibility challenge mitigated?
- Visibility – Can the component and/or system being worked on visible or do special remote viewing measures be taken?
- Testability – Can proper testing enable faults to be predicted and/or detected and isolated to the necessary level of detail to permit cost-effective preventative and corrective maintenance to occur? This is a critical part of Inspectability – replacing components proactively at an agreed upon percentage of their MTBF or predicting failures and proactively intercepting the problem before it occurs.
- Reliability Centered Maintenance (RCM) – Is there a discipline means of identifying preventive maintenance tasks? Originally used in the aircraft industry, RCM utilizes information from the FMECA to identify items that are the most critical to system availability. The resulting analysis can then be used identify and schedule preventative maintenance tasks on a scheduled, periodic basis to prevent failures while the equipment is in operation – this goes well beyond the routine maintenance activities such as lubrication and adjustments that are needed to keep systems in operation.
- Complexity – How many parts are used in the component and/or system? Are the parts standard or special purpose? Generally, simpler systems tend to be more reliable and maintainable than do complex ones.
- Standardization and Interchangeability – Can the failed or malfunctioning unit be swapped around or readily replaced by an identical unit with no need for recalibration? Standardization of systems, parts, tools, and procedures reduce the training necessary and the risk to readiness. Modular designs also lend themselves to higher reliability and maintainability.

4.3 Availability

Maintainability and reliability are the two major system characteristics that combine to form the commonly use effectiveness index – availability. The overall objective is to of the NCSX Project is to provide an experimental device with a high operational availability. The GRD defines this overall RAM objective in terms of the number of plasma discharges achieved in a run period vs. the number planned. Recognizing that availability may be degraded during the initial shakedown and commissioning phases, the GRD does not apply this requirement until these phases are completed. An operational availability goal of greater than 75% is specified in the GRD.

NCSX will rely on sound engineering practice to assure high availability of the overall NCSX device; this has been a tried-and-true approach on similar scale fusion devices. Some of the sound engineering practices that are being applied include:

- Applying design principles that promote reliability. Among these are employing an adequate factor of safety on mechanical and electrical stresses, avoiding unnecessary complexity, using proven design approaches and well characterized materials successfully utilized on other fusion devices, etc.
- Optimizing designs for reliability and maintainability through systematic evaluation of design options, including constructability reviews of the design to ensure ease in assembly, but also ease in access, inspection, and maintainability.
- Performing failure modes, effects and criticality analyses (FEMECAs) for RAM design improvements and verification; and
- Employing peer reviews as a mechanism to enhance the design process.