TEMPORARY CHANGE REQUEST

TCR NO.TCR-ENG-007,R1-001
(e.g., TCR-ENG-021,R0-001)

The Temporary Change Request (TCR) Form is to be used to process urgent or minor changes for PPPL Policies, Organization/Mission Statements and Procedures. The TCR should be used when changes are:
1) urgent, and can not wait the 2-4 week period for Department Head review/comment, or
2) minor, and do not warrant Department Head review.

Person Requesting Change: Jim Graham **Phone Ext:** 2701

Department Name: Best Practices

Document Number: ENG-007 **Revision No.:** 1

Document Title: Reliability, Availability and Maintainability (RAM) Modeling and Apportionment

Reason for change:
Added Management System information, Training information and Records Retention information and added an updated link for RAM Guide.

Change description: (Summarize and attach changed pages, with changes clearly indicated)
1. Added Management System information
2. Added Training information
3. Added Records Retention information

1. Does this TCR significantly alter the intent or scope of the document? **YES:**____ **NO:X**____

2. Does this TCR significantly impact **ES&H**? **YES:**____ **NO:X**____

If 1 or 2 is **YES**, Explain why the changes should not be routed for Department Head review:

Tim Stevenson **12/16/2014**
Department/Division Head Approval **Date**

John DeLooper **12/17/2014**
Head, Best Practices and Outreach/designee **Date**

Release/Effective date of this TCR: **12/17/2014**

Incorporate this TCR into next revision of this document? **YES:X**___ **NO:**____

Subject:	Effective Date:	Initiated by:
Reliability, Availability, and Maintainability (RAM) Modeling and Apportionment	November 30, 2011	Associate Director, Engineering and Infrastructure
	Supersedes: ENG-007 dated 6/11/99	Approved: Director

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Management System (Primary): 03.00 ENGINEERING (ENG)
Management System Owner: Associate Laboratory Director for Engineering and Infrastructure
Management Process: 03.04 Engineering Programs and Processes
Process Owner: Associate Laboratory Director for Engineering and Infrastructure
Sub-Process: 03.04.03 Engineering and Design Processes
Sub-Process Owner: Head, Project Management
Subject Matter Expert Head, Project Management TCR ENG-007,R1-001

Applicability

This procedure applies to all activities at PPPL where the need for Reliability, Availability, and Maintainability (RAM) Modeling and Apportionment is required. The RAM assessment shall be performed for the required by project requirement documents, work planning documents, or by management directive. The RAM shall be documented as part of the projects' system design processes and may be included as part of a project's safety documentation (e.g., Safety Analysis Report, Safety Assessment Document, etc.).

Introduction

This procedure establishes the requirements for the preparation, review, and release of the RAM. Brief guidance on performing a RAM is available in the Attachments. However, the reader should be aware that this is a complex topic that is the basis for an entire field of engineering and cannot be adequately covered in a relatively brief procedure. More detailed information is available through listed references.

Reference Documents/Organizations

IEC Standard 60300 Series A series of IEC standards addressing Reliability, Availability, and Maintainability under the generic topic of "Dependability Management"
Reliability Engineer's Toolkit (2005) - a joint publication of the Reliability Information and Analysis Center (RIAC - http://www.theriac.org/) and the Data and Analysis Center for Software (DACS – www.thedacs.com) Government Industry Data Exchange Program (GIDEP – www.gidep.org)
American Society for Quality (ASQ) Reliability Division
IEEE Reliability Society
ENG-029 - Technical Definitions and Acronyms

Definitions

Availability	Availability is a measure of readiness for a system to be in an operational state to support a mission objective. Availability is measured by the user as a function of how often failures occur and corrective maintenance is required, how often preventive maintenance is performed, how quickly indicated failures can be isolated and repaired, how quickly preventative maintenance can be performed, and long logistics support delays contribute to the down time.
Maintainability	Maintainability is the ability of an item to be retained in, or restored to, a specified condition when maintenance is performed by personnel having specified skill levels, using prescribed procedures and resources, at each prescribed level of maintenance and repair.
Reliability	Reliability is the probability that an item will perform a required function under stated conditions for a specified period of time

Procedure

Responsibility	Action
Responsible Line Manager (RLM)	1. Assigns individual to perform RAM (analyst) and another individual to review it (reviewer). The reviewer shall be qualified by having like or greater expertise and technical experience as the analyst. Refer determination of selection to the Associate Director for Engineering and Infrastructure if necessary.
	2. Provides guidance to the analyst and reviewer on the level of detail for the RAM. RAM analysis may continue down to the component level, if desired, or stop at a predefined intermediate level.
Analyst	3. Describes system under analysis and either prepares system diagrams or uses existing documentation to depict all major components and their performance criteria. The level of assembly will vary with the level of the analysis.
	4. Performs RAM using the guidance of Attachment 1.
	5. Documents results using appropriate format.
	6. Signs RAM and provides it to the reviewer.
Reviewer	7. Reviews RAM for technical content and signs if no significant problems are identified. Otherwise discusses the RAM with the analyst. ***Note: No RAM should ever be performed without a reference and/or link to an existing Work Package (WP).***
Analyst	8. Files RAM in the Operations Center.

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TRAINING (SECTION REQUIRED FOR ALL PROCEDURES)

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Author

1. Specifies the appropriate training methods and means (below) and obtains concurrence of the Management System Owner and the Management Process Owner.

   A. Target Audience: New Project Managers
   Instructor: Head, Project Management
   Training Method:
   X Read only

   Frequency:
   X Once only

Management System Owner or Designee

2. Notifies the Human Resources Training Office of the training so that they will be aware of the training requirements and be able to provide assistance and guidance in the course development, implementation, tracking, and maintenance.

Records Requirements Specific To This Procedure

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Records Custodians must assure records are maintained as follows:

Record Title	Record Custodian	Location	Retention Time
RAM Summary Form	Operations Center	Operations Center	See Record Schedule for specific Project Type *Reference Admin 17, Cartographic, Aerial Photography, Architectural & Engineering Records (30.c)*

Attachments:

1. Guidance on performing RAM Modeling and Apportionment
2. RAM Summary Form

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Purpose

This attachment provides guideline involved in performing Reliability, Availability, Maintainability Modeling and Apportionment (RAM). The guidelines in this attachment are taken from several sources:

- The DOE Guide for Achieving Reliability, Availability, and Maintainability - August, 2005 (http://www.theriac.org/pdfs/DoD%20RAM%20Guide%202005%20-%20Modified.pdf) – no number assigned – and TCR ENG-007,R1-001
- A Technical Report for the PPPL Compact Ignition Tokamak (CIT) titled: "*CIT Tokamak Mission Analysis and Reliability/Availability Apportionment to Major Systems:*, performed by Evaluation Associates, Inc., January 1988

There are three primary tasks needed to perform RAM:

1. Establishing RAM requirements.
2. Using the RAM requirements during the design of the systems or their operations.
3. Validating the design.

Each will be described further.

Establishing RAM requirements

This task may be accomplished via the following steps:

1. Define the top level project RAM requirements. For fusion devices, this is usually defined by three factors which should be defined in the General Requirements Document (GRD):
   a) *Operational availability* - This is typically defined as the ratio of shots per hour in operation in which the reactor is operational at the required level to the shots per hour that could be achieved with no component or software failures. Generally this will be on the order of $\geq 80\%$.
   b) *Full mission reliability* - This is typically defined as the probability of achieving XXXX full-power pulses without a failure that directly or indirectly compromises the project mission by precluding operation at full power for more than one calendar year. Generally this will be on the order of $\geq 90\%$.
   c) *Single shot reliability* - This was defined as the probability of acquiring the necessary data to achieve the goal of a shot. Generally this will be on the order of $\geq 90\%$.
2. Define the project functions or systems.

   Fusion projects can be broken down into major systems including: vacuum vessel, TF coils, PF coils, heating systems, AC power, etc.
3. Identify realistic and achievable RAM requirements for each project function or system. The products of the availability and reliability for each system must equal the project availability and

reliability. The General Requirements Document for each project should provide some guidance in this area.

4. For each project function or system, identify the next lower functions or systems and assign RAM requirements. At each step, the products of the availability and reliability of each lower level system must equal the system availability and reliability.

   The model for the PF System is(using CIT as an example):

   a) External PF Ring Coil (10 in series)

   b) Coil case (10 in series)

   c) Central Solenoid Coil (6 in series)

   d) Internal PF Coil (6 in series)

   e) Passive Stabilization Elements (2 in series)

   f) Solenoid Support Structure (1)

   g) PF Power & Coolant Feed (1)

   h) PF Local Control Instrumentation & Control (1)

   The associated reliability equation is:

   $$R_{PF} = (R_a R_b)^{10} (R_c R_d)^6 R_e^2 R_f R_g R_h$$

   Appropriate reliability values would be chosen for the eight subsystems of the RF system that are consistent with this equation.

5. Continue breaking the system down into lower level components and assigning reliability to the level jointly agreed upon with the RLM.

<u>Using the RAM requirements during the design of the systems or their operations.</u>

Various design tools or techniques may be used to achieve the RAM requirements including redundancy, modularity, reliability vs. maintainability trade-off studies, and parts derating. Other tools such as a spare parts program or a preventive maintenance program may be used to achieve the RAM operational requirements.

Validating the design

Various tools exist for the design stage to validate that RAM apportionment has been achieved. They include failure modes and effects, fault tree, Markov, event tree, sneak circuit, and maintenance engineering analyses.

1. Failure Modes and Effects Analysis – Identify the various ways a system can fail and the effects of the failure. See ENG-008 for additional information.
2. Fault Tree Analysis – Identify undesirable effects; then try to identify all possible failure modes leading to these events.
3. Markov Analysis – Use state diagrams and differential equations to identify failure probabilities.
4. Event Tree Analysis – Model the system conditions that can result in a failure or a degradation of the system.
5. Sneak Circuit Analysis – Identify latent paths that cause unwanted functions to occur or that inhibit desired functions.
6. Maintenance Engineering Analysis – Estimate maintenance requirements (staffing, tools, equipment) and downtimes.

Published reliability data for commercially available components might also be used to verify the reasonableness of the assigned availability and reliability. The Government Industry Data Exchange Program (GIDEP – www.gidep.org) and the Air Force Research Laboratory Information Directorate which is part of the Air Force Research Laboratory is located in Rome, NY (formerly the Rome Laboratory(http://www.wpafb.af.mil/afrl/ri/) are sources of such data.

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PPPL RAM Summary Form

RAM # _____ Revision # _____ WP #: _____
(ENG-032)

Purpose of RAM: (Define why the RAM is being performed.)

References (List any source of design information including computer program titles and revision levels.)

Assumptions (Identify all assumptions made as part of this calculation.)

RAM (RAM is either documented here or attached)

Conclusions (Specify whether or not the purpose of the calculation was accomplished.)

Cognizant Engineer's printed name, signature, and date

_____

I have reviewed this RAM and, to my professional satisfaction, it is properly performed and correct.

RLM's printed name, signature, and date

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