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ESS RELIABILITY AND AVAILABILITY APPROACH

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Abstract

Reliability and availability are key metrics for achieving the scientific vision of the European Spallation Source, ESS in Lund/Sweden. The approach taken to define the requirements and to analyze and improve these metrics is described in this contribution.

This paper describes the basis for ESS reliability and availability requirements. It describes where the requirements come from and how they are allocated among the subsystems. It puts the operation, users and the different subsystems' behavior in context, in order to provide a coherent framework to develop the RAMI* analyses for each ESS subsystem. The requirements shown here are not yet finalized and may change in the future; however, they are considered to be the base for the RAMI studies.

INTRODUCTION

ESS is a neutron source facility that will serve the scientific community by delivering spallation neutrons to a suite of scientific instruments where scientific users will be able to perform neutron scattering experiments. ESS will consist of a 5MW accelerator that accelerates protons to 2GeV, a rotating tungsten target where the spallation process takes place and the instruments where the users perform the experiments [1]. From a user perspective, the reliability and availability of the neutron beam and the neutron scattering instruments are key performance aspects of the ESS facility. High reliability and availability will ensure the execution of scientific experiments.

The methodology used to obtain the requirements considers not only the availability and reliability figures but also the specific needs extracted from user expectations of the neutron source in order to successfully perform their experiments. A top-down requirements allocation is being developed at the same time that bottom-up analyses are being undertaken. The experiments expected at ESS and their needs in terms of neutron beam performance (reliability, availability and quality) are described, as well as the tools used to analyze them. This contribution is the first step for these studies at ESS.

ESS RELIABILITY AND AVAILABILITY REQUIREMENTS

ESS requirements have been divided into Neutron Source and NSS (Neutron Scattering Systems) requirements. The Neutron Source includes all systems that contribute to the neutron beam production: Accelerator, Target, Integrated Controls System (ICS) and Site Infrastructure (SI) (only the conventional subsystems that could affect the neutron beam production). NSS include the Instrument Systems (including Guide Bunker & Monolith Shroud), Science Support Systems (SSS) and the part of SI that supplies to the NSS subsystems.

The work presented here is related to the neutron beam requirements.

Neutron Beam Needs for the Users

It was decided that the main goal for ESS is that "*At least 90% of the users should receive a neutron beam that will allow them to execute the full scope of their experiments*". Following this goal, the different kinds of experiments and their needs in order to execute their full scope were studied.

There will be two kinds of experiments: the kinetic and the integrated-flux experiments [2]. The kinetic experiments are expected to constitute about 10% of the total number of experiments that will be performed at ESS. For these experiments it is important to have a continuous beam for the duration of the measurement (an experiment is usually composed of several measurements). The duration is typically between a few seconds and several minutes. On the other hand, integrated-flux experiments (90% of the total number of experiments) are not affected by short beam interruptions; however, it is important for them to receive a high integrated neutron flux for the time allocated to them. The integrated neutron flux received by the experiments is directly related to the beam availability and the proton beam power. The duration of these experiments typically goes from one to seven days.

Neutron Beam Requirements to Satisfy the Users

Taking into account the specific needs for the experiments as well as the best practices and the operational flexibility, the following neutron beam requirements were extracted [3]:

Kinetic experiments: *"A reliability of at least 90% should be provided for the duration of the measurement. The measurement will be considered failed when the beam power is reduced to less than 50% of the scheduled power for more than 1/10th of the measurement length"*.

Integrated-flux experiments: *"For the duration of the experiment at least 90% of the experiments should have at least 85% of beam availability and on average more than 80% of the scheduled beam power. The beam will be considered unavailable when its power is less than 50% of its scheduled power for more than one minute"*.

These requirements were treated in order to obtain useful, traceable and consistent requirements that will be

* Reliability, Availability, Maintainability, Inspectability

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used as individual requirements for each ESS subsystem. In addition, these requirements will allow a consistent comparison of the performance of ESS with other facilities.

To do so, bins of beam trips (i.e. interruption of neutron beam operation) were created, with a maximum number of trips accepted, in order to fulfill the requirements coming from the users. The time scales used to create the bins were selected to fulfill several purposes: relationship with the experiments and the trips that would lead to their failure, easy comparison with other facilities and future operation and maintenance expected at ESS.

After a first comparison with Spallation Neutron Source (SNS) in Fig. 1, the data showed that ESS requirements for short beam trips (up to 6 minutes) seem achievable. However, beam trips from 20 minutes to one day were slightly more restrictive than SNS operational data. This indicates that an important effort will be needed to reach these requirements. Nevertheless, SNS seems to have improved their reliability since 2013.

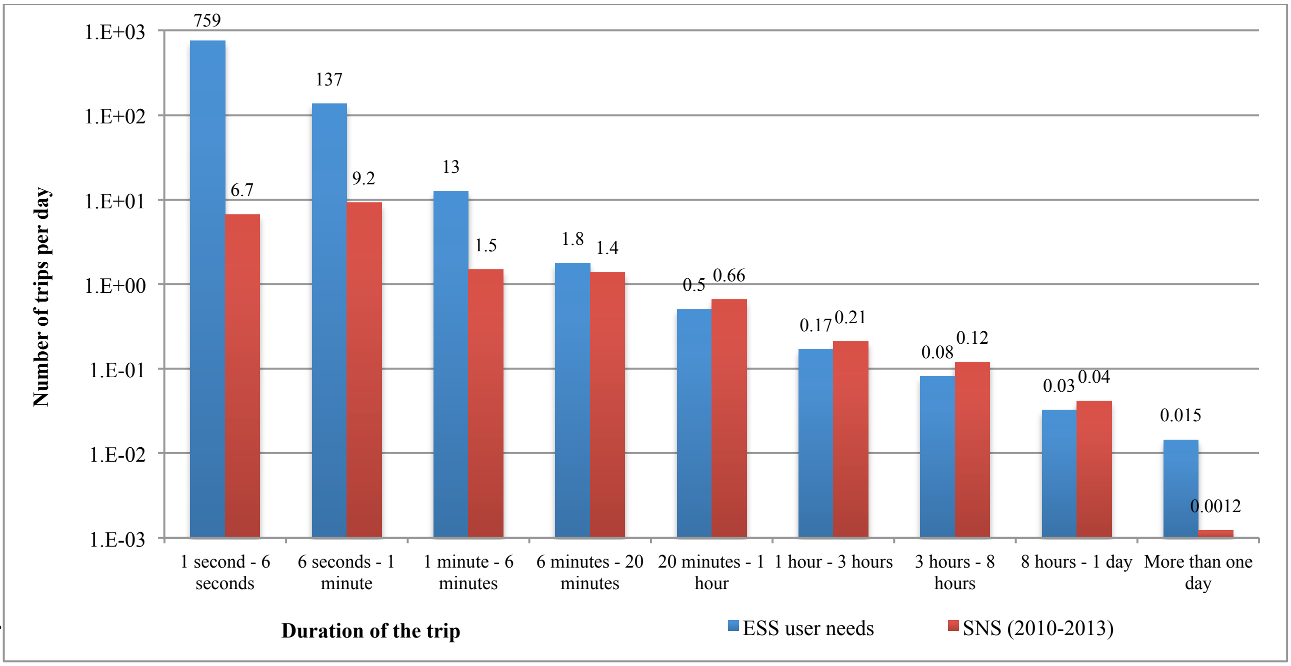

Figure 1: Maximum number of trips needed for ESS users compared to SNS operation from 2010 to 2013.

Table 1: Proposed ESS Requirements of Maximum Number of Beam Trips

Trip duration	Max. number of trips
1 second - 6 seconds	120 trips per day
6 seconds - 1 minute	40 tips per day
1 minute - 6 minutes	5 trips per day
6 minutes - 20 minutes	350 trips per year
20 minutes - 1 hour	99 trips per year
1 hour - 3 hours	33 trips per year
3 hours - 8 hours	17 trips per year
8 hours - 1 day	6.7 trips per year
1 day - 3 days	2.9 trips per year
3 days - 10 days	1 every 4 years
more than 10 days	1 every 10 years

ESS Neutron Beam Requirements

In order to achieve the high level of availability demanded for the ESS, some changes were made to the bins obtaining a better overall beam availability:

- A tighter requirement has been set for short trips (up to 6 minutes).
- For the users, any trip of more than 1 day will imply the need to stop the experiments. Two additional bins were included (3-10 days and more than 10 days).

The proposed ESS requirements are shown in Table 1 (one year consists of 200 days of operation).

DEGRADED MODE OPERATION

In addition to the maximum number of beam trip requirements, the possibility of reducing the proton beam power (lowering beam current, beam energy, repetition rate…) has been defined as an option for operation under non-nominal conditions since some accelerator and target failures may imply to reduce proton beam power instead of stopping the beam.

The following definition of such degraded mode operation has been set in order to take the users' needs into account and at the same time consider normal practices at neutron sources to obtain a realistic operation performance:

"It is possible to decrease proton beam power to 50% of the scheduled beam power without considering it a beam trip. However, the average proton beam power over

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10 days shall be higher than 80% of the scheduled beam power".

This definition may change in the future, but it is a useful way of describing how ESS is going to operate and gives the flexibility needed to perform the RAMI analyses. This flexibility follows the general comment given by the user community: users will prefer beam availability to beam power.

REQUIREMENTS ALLOCATION

A preliminary allocation of the requirements among the different ESS systems has been done. It has been done following expert opinions and experiences from other facilities. Once the first results from the bottom-up analysis are obtained, some modifications could be done.

SNS data have been used for the allocation of the requirements. It was considered that the SNS and the ESS have a similar distribution of beam trips. Some assumptions were made for the differences between the two facilities. For systems where no comparison was possible, designer and expert opinions were used to obtain typical downtimes and estimations of failure frequencies.

The proposed allocation of the ESS requirements are shown in the next table.

Table 2: Proposed Maximum Number of Beam Trips Allocated to ESS Subsystems. ICS stands for Integrated Controls System and SI for Site Infrastructure.

Downtime duration	Accelerator	Target	ICS	SI
1 second - 6 seconds	120 per day	-	-	-
6 seconds - 1 minute	40 per day	-	-	-
1 minute - 6 minutes	4.8 per day	-	40 per year	-
6 minutes - 20 minutes	1.7 per day	-	10 per year	-
20 minutes - 1 hour	90 per year	2 per year	4 per year	3 per year
1 hour - 3 hours	29 per year	1 per year	2 per year	1 every 2 years
3 hours - 8 hours	15 per year	1 every 2 years	1 every 2 years	1 every 2 years
8 hours - 1 day	5.5 per year	1 every 2 years	1 every 5 years	1 every 3 years
1 day - 3 days	2.3 per year	1 every 2 years	-	1 every 10 years
3 days - 10 days	1 every 5 years	1 every 20 years	-	-
more than 10 days	3 every 40 years	1 every 40 years	-	-

Some systems do not have requirements in one or more of the bins. For those cases, it is assumed that the probability of having one of these trips is very small (minimum 2 orders of magnitude lower than the ESS requirement). For example, the probability for SI of having a failure leading to more than 10 days of downtime should be lower than 1 in 1000 years.

ESS requirements shown in this contribution are slightly tighter than SNS operational figures. The requirements, compared to SNS operational data seem possible to achieve if enough resources and effort is put into it. SNS experience showed that it requires a lot of investment and good organization to reach their availability figures.

CONCLUSIONS

The global ESS availability figure is not the most important for the users. What is important for them is the distribution of beam trips. The requirements obtained in this study and its allocation follows the importance of the different downtime lengths and their consequences for the users. At the same time, the global ESS performance has been taken into account.

Bottom-up RAMI analyses have already started. Their main goal is to check if the requirements would be achieved with the current systems design. Recommendations for design, manufacturing, tests, maintenance procedures and operation among others are being obtained as an outcome of these studies.

Relation between consequences of failures in subsystems and the users is not straightforward. Clear reliability requirements with a proper allocation allow simplifying analyses and discussions at lower levels of the project. Moreover, such requirements make it easier for colleagues without expertise in reliability to understand what they should achieve and how.

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