LA-UR-20-26666
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Title: Overview of the MCNP6® SQA Plan and Requirements

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Intended for: Report

Issued: 2020-08-27

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memorandum

Monte Carlo Codes, XCP-3
X Computational Physics Division

To: Distribution

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Symbol: XCP-3:20-008
LA-UR-20-26666

Date: August 27, 2020

Subject: Overview of the MCNP6® SQA Plan and Requirements

General Overview

For all X Computational Physics Division (XCP) software under the Associate Laboratory Directorate for Weapons Physics (ALDX), the Weapons Research Services Secure Networks and Assurance Group (WRS-SNA) manages the software quality assurance (SQA) plan, requirements and guidance with respect to development processes and tools to meet the broader LANL SQA requirements. Each XCP software product is categorized into one of three software types: Safety Software, Non-Safety Risk Significant Software, and Non-Safety Commercially Controlled Software. Within ALDX, all software that is

- categorized as Safety Software and Non-Safety Risk Significant Software, the LANL P1040 *Software Quality Management* plan is followed;
- categorized as Non-Safety Commercially Controlled Software, the WRS-SNA WRS-AD-0010U *Software Quality Assurance Program Plan* is followed, which derives from the LANL P1040 *Software Quality Management* plan.

Additionally, WRS-AD-0010U identifies Institute of Electrical and Electronics Engineers (IEEE) as its standard. The NNSA NAP-24A *Weapon Quality Policy* requires that a standard be selected, and at LANL, the IEEE software engineering standard is preferred.

P1040 is derived from the LANL SD330 *Los Alamos National Laboratory Quality Assurance Program*, and subsequently the DOE O 414.1D *Quality Assurance* order. Figure 1 describes the SQA flow-down that ultimately applies to the SQA plan and procedures within LANL's ALDX. Figure 2 defines the required procedure for each software product developed and maintained in the ALDX with the required procedure dependent on software categorization.

LANL Form 2033 *Safety/Non-Safety Software Determination, Categorization, and Software Risk Level (SRL)* is used to determine the software categorization. In the case where the software is categorized as Non-Safety Commercially Controlled Software, WRS-FORM-0001U *ADX Software Impact Grading From* is then used to determine whether it is High, Medium or Low

Impact. This grading determines which components within the WRS-AD-0010U SQA plan are required to be followed.

[1]MCNP6® Categorization and Grading

In 2018, using LANL Form 2033, the MCNP6 code was categorized by the XCP division as **Non-Safety Commercially Controlled Software**, provided in Appendix A. Using WRS-FORM-0001U, the MCNP6 code was graded as a **Medium Impact** software product, provided in Appendix B.

Given these determinations, the WRS-AD-0010U SQA plan is followed for all MCNP6 developments, documentation and code releases (see highlighted boxes in Figures 1 and 2).

For the applications and uses of versions of the MCNP6 code that are developed and released by the Monte Carlo Codes group (XCP-3), the MCNP6 code is not controlled for and should not be used for safety significant applications unless qualified to do so by individual users of the code for their specific areas of application.

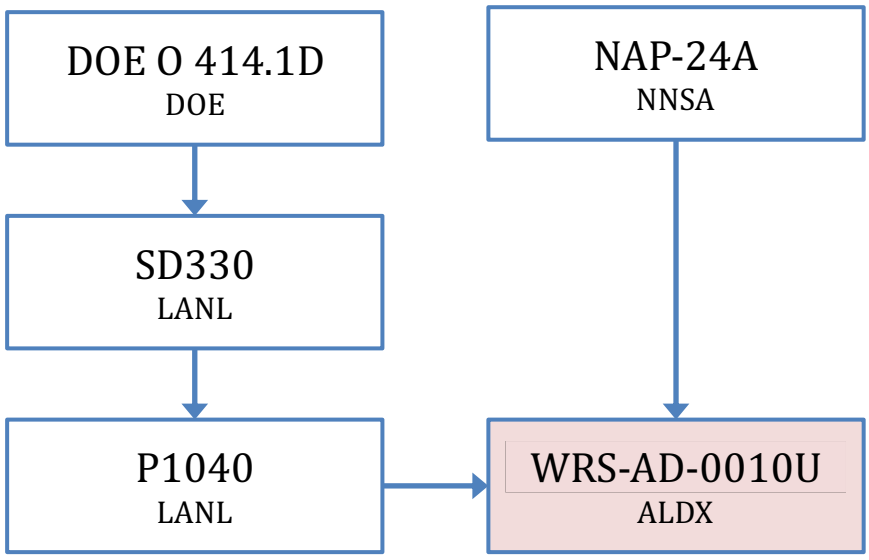

Figure 1. SQA Documents

[1] MCNP® and Monte Carlo N-Particle® are registered trademarks owned by Triad National Security, LLC, manager and operator of Los Alamos National Laboratory. Any third-party use of such registered marks should be properly attributed to Triad National Security, LLC, including the use of the ® designation as appropriate. For the purposes of visual clarity, the registered trademark symbol is assumed for all references to MCNP within the remainder of this document.

<table>
<tr><th colspan="4">Procedural Scope by Software Type</th></tr>
<tr><td>Safety Software</td><td>Non-Safety
Risk Significant Software</td><td colspan="2">Non-Safety
Commercially Controlled Software
(includes all ALDX in-scope software)</td></tr>
<tr><td rowspan="2" colspan="2">Follow P1040</td><td>High Impact</td><td>Medium Impact</td><td>Low Impact</td></tr>
<tr><td colspan="3">Follow WRS-AD-0010U</td></tr>
</table>

Figure 2. SQA Plan Requirements Process

Recommendations for Users of the MCNP6 Code for Safety and/or Risk Significant Applications

The general purpose MCNP6 particle transport code can be used for many applications including but not limited to radiation protection and dosimetry, radiation shielding, radiography, medical physics, nuclear criticality safety, detector design and analysis, nuclear oil well logging, accelerator target design, fission and fusion reactor design, and nuclear decontamination and decommissioning. It would unreasonable for the code development team to develop the code under the strict ASME NQA-1-2008 (NQA-1) *Quality Assurance Requirements for Nuclear Facility Applications* documented standards for all of these application areas. More importantly, this would be unusable by all users of the code given that **all users must qualify their version of the MCNP6 code and data for their particular uses and applications**. Specifically, for LANL users the MCNP6 code usage needs to follow the LANL P1040 *Software Quality Management* process if it will be used in safety and/or risk significant applications. For other users and institutions, the requirements may vary based on how each institution chooses to follow the NQA-1 and other international standards.

As part of the qualification of the MCNP6 code for specific applications, it is recommended and may be required that a suite of qualification tests be developed to cover the application areas of interest. Within the XCP-3 Monte Carlo Codes group, throughout the development of MCNP6 features and code improvements, extensive testing is routinely performed. Verification and validation (V&V) tests provided and documented with the MCNP6 code, covering criticality, shielding and many other physical capabilities, may be relevant and useful to supplement or fulfill user-specific qualification testing for a limited set of application areas. As an example, version 6.2 of MCNP includes several developer curated V&V test suites, with results documented in "MCNP6.2.0 Release Testing", LA-UR-17-29011 (2017).

In addition to these qualification tests, which may need to be exercised on a regularly occurring basis defined in the user-specific SQA plan, access control mechanisms over the MCNP6 code, executable, and all necessary data files required to execute the code must be in place to ensure the qualified code and data are not altered in any fashion. This may include the use of access control mechanisms to ensure that the MCNP executable cannot be modified, the use of

checksums to ensure that the executable has not been modified, and the use of in-use tests to ensure that neither the MCNP6 executable nor any operating system libraries have been detrimentally modified. The end user should be cognizant of the system libraries for which the MCNP6 code depends and any changes to such system libraries should be tracked. Additional strict access/change control to the system libraries may be necessary as well.

In order to qualify the MCNP6 code for a specific application use, it is possible the user will need to go through the commercial grade dedication process if their application falls in a safety or risk significant application area.

Specifically, for nuclear criticality safety applications, where MCNP6 is frequently used in a more safety/risk significant application area, DOE-STD-3007-2017 *Preparing Criticality Safety Evaluations at Department of Energy Nonreactor Nuclear Facilities* states:

> *Calculational techniques may be hand calculation methods or computer-based neutron transport calculations. The neutron transport computer code systems listed below are developed and maintained through rigorous expert review of neutron transport theory, cross section data, and Monte Carlo methods in accordance with DOE software quality assurance requirements. These code systems are distributed by the Radiation Safety Information Computational Center at Oak Ridge National Laboratory. The following code systems are accepted programs for use in NCS applications when used in accordance with a site-specific software quality assurance program for classifying and controlling software:*
>
> - *SCALE: A Comprehensive Modeling and Simulation Suite for Nuclear Safety Analysis and Design*
> - *MCNP®: Monte Carlo N-Particle Transport Code System*
> - *COG: Multiparticle Monte Carlo Code System for Shielding and Criticality Use*
>
> *All pertinent calculational results shall be reported. Where referenced calculations or reports are used to support the results of the evaluation, a summary of the referenced calculations should be included. Plots of data should be clearly labeled. Descriptions/labels of individual computer runs should indicate the physical attributes of the system being analyzed. Estimated uncertainties in the results (e.g., statistical uncertainties associated with Monte Carlo calculations) and analyzed sensitivities to modeling simplifications that are not bounding (e.g., effects of homogenization, dimension or geometry modifications) should be included here as well.*

Regardless of this statement in DOE-STD-3007-2017, which may allow these specific users to bypass the commercial grade dedication process, each nuclear criticality safety site must validate the MCNP6 code and data with benchmarks which cover their area(s) of application. Additionally, they must have their own SQA plan for qualification testing with access control mechanisms in place to protect the code and data from detrimental changes.

Acronyms

ASME	American Society of Mechanical Engineers
DOE	Department of Energy
NNSA	National Nuclear Security Administration
LANL	Los Alamos National Laboratory
ALDX	Associate Laboratory Directorate for Weapons Physics (within LANL)
XCP	X Computational Physics Division (within ALDX)
XCP-3	Monte Carlo Codes Group (within XCP)
WRS	Weapons Research Services Division (within ALDX)
WRS-SNA	Secure Networks and Assurance Group (within WRS)

References

P1040	LANL	*Software Quality Management*
WRS-AD-0010U	ALDX	*Software Quality Assurance Program Plan*
NAP-24A	NNSA	*Weapon Quality Policy*
SD330	LANL	*Los Alamos National Laboratory Quality Assurance Program*
DOE O 414.1D	DOE	*Quality Assurance*
Form 2033	LANL	*Safety/Non-Safety Software Determination, Categorization, and Software Risk Level (SRL)*
WRS-FORM-0001U	ALDX	*ADX Software Impact Grading From*
ASME NQA-1-2008	ASME	*Quality Assurance Requirements for Nuclear Facility Applications*
DOE-STD-3007-2017	DOE	*Preparing Criticality Safety Evaluations at Department of Energy Nonreactor Nuclear Facilities*

MER:mer

Distribution:

MCNP Website, mcnp.lanl.gov

Appendix A

2018 MCNP6, Form 2033 (4 pages)

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Form 2033

Reference No: ____

The Software Owner RLM must retain completed forms as a record.

Safety/Non-Safety Software Determination, Categorization, and Software Risk Level (SRL)

(See Page 5 for Guidance)

Part 1: Document the rationale supporting the reasonable probability that the software may be safety software, or risk significant software.

1.1 Excluding personal productivity software that does not provide calculation output (e.g., e-mail software, presentation software), indicate whether the software is or will be used in connection with the design, analysis and/or operation of:

- ☐ a nuclear (including radiological) facility (Ref. LANL Nuclear Facility List, Conduct of Operations Resources Website), or
- ☐ an accelerator, live-firing range, biological hazard facility, high explosive facility, or moderate- or high- chemical hazard facility as determined using SBP111-1, *Facility Hazard Categorization and Documentation*; or
- ☒ LANL's Essential Functions as described in SEO-COOP-006, *LANL COOP [Continuity of Operations] Plan*.

Provide supporting comments (as necessary to document the selection above).

ADX COOP, ADX:18-010, identifies simulation source codes as being records of essential functions which MCNP is a simulation source code.

Part 2: Document the software information, software application(s) and software function(s). A separate form may be used for each software item or one form may be used for multiple software items.

2.1 Provide software name(s).	2.2 Provide software version(s).	2.3 Indicate software owner (SO).	2.4 Indicate SO organization.
MCNP	6	Avneet Sood	XCP-3

2.5 Provide a description of the specific facility application(s) to sufficient detail to allow the software to be readily traceable to the point(s) of application within the facility. Include technical area (TA) and building number; or, site-wide or Facility Operating Directorate (FOD)-wide use. Add other descriptive information as required.

Not applicable.

2.6 Indicate System, Structure or Components (SSCs) controlled or affected by the software. Indicate NA if not applicable.

NA

2.6.1 Provide SSC name(s).

2.6.2 Provide functional requirement(s) of the software associated with the SSC.

2.6.3 Provide reference document(s) describing the SSC/software.

Provide supporting comments (as required).

2.7 Indicate facility classification (SBP111-1), design, or analysis controlled or affected by the software. Indicate NA if not applicable.

NA

2.7.1 Provide facility classification, design or analysis name.

2.7.2 Provide software functional requirement(s) associated with the facility classification, design or analysis.

2.7.3 Provide reference document(s) describing the facility classification, design, or analysis.

Provide supporting comments (as required).

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ADX-Sign-2018-125

2.8 Indicate the hazard control, Safety Management Program (SMP) and or technical safety requirements (TSRs) controlled or affected by the software. Indicate NA if not applicable. NA 2.8.1 Provide the hazard control, SMP and/or TSR name. 2.8.2 Provide the software functional requirement(s) for the hazard control, SMP and/or TSR. 2.8.3 Provide reference document(s) describing the hazard control, SMP and/or TSR. Provide supporting comments (as required).

Part 3: Determine whether the software type is (1) safety software; or (2) non-safety software and the associated category for each type.		
3.1 Check **one** of the following (3.1.1 through 3.1.5) to determine one of the two software types (safety software or non-safety software) and one of the associated 5 categories for each type (i.e. Categories include SSS, SHADS or SMACS for safety software; and, Risk Significant or Commercially Controlled for non-safety software). **Note**: If software is determined to be safety software or risk significant software, complete all parts of this form. If software is determined to be commercially controlled software, complete all parts of this form **except for Part 4**.		
3.1.1 Safety software: SSS ☐	This is software for a nuclear (including radiological) facility that performs, or will perform a safety function as part of a Structure, System, and Component (SSC) and is cited in either (a) a Department of Energy (DOE)-approved documented safety analysis; or, (b) an approved hazard analysis per DOE P 450.4A, *Integrated Safety Management Policy* and 48 Code of Federal Regulations (CFR) 970-5223-1, *Integration of Environment, Safety, and Health into Work Planning and Execution*. This is safety software and is categorized as Safety System Software (SSS). Provide supporting comments (as required).	
3.1.2 Safety software: SHADS ☐	This is software that is used, or will be used to classify, design, or analyze nuclear (including radiological) facilities. This software is not part of an SSC, but helps to ensure the proper accident or hazards analysis of nuclear (including radiological) facilities or an SSC that performs a safety function. This is safety software and is categorized as Safety and Hazard Analysis Software and Design Software (SHADS). Provide supporting comments (as required).	
3.1.3 Safety software: SMACS ☐	☐	This is software that performs or will perform a hazard control function in support of nuclear (including radiological) facility radiological safety management programs (SMPs) or technical safety requirements (TSRs). This is safety software and is categorized as Safety Management and Administrative Controls Software (SMACS). Provide supporting comments (as required).
	☐	This is software that performs, or will perform a control function in support of a nuclear (including radiological) facility necessary to provide adequate protection from nuclear (including radiological) facility radiological hazards. It supports eliminating, limiting, or mitigating nuclear hazards to workers, the public, or the environment as addressed in 10 CFR 830, *Nuclear Safety Management*, 10 CFR 835, *Occupational Radiation Protection*, and the Department of Energy Acquisition Regulation (DEAR) Integrated Safety Management System (ISMS) clause 48 CFR 970.5223-1, *Integration of Environment, Safety, and Health into Work Planning and Execution*. This is safety software and is categorized as Safety Management and Administrative Controls Software (SMACS). Provide supporting comments (as required).
3.1.4 Non-safety software: Risk Significant ☐	This is software that is, or will be used for any of the purposes that safety software is used for only such purposes are in or for an accelerator, live-firing range, biological hazard facility, high explosive facility, or moderate- or high- chemical hazard facility OR, failure of the software would prevent LANL from performing Essential Functions as described in SEO-COOP-006, *LANL COOP [Continuity of Operations] Plan*. This is non-safety software and is categorized as Risk Significant software. Provide supporting comments (as required).	

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3.1.5 Non-safety software: Commercially Controlled ☒	This is software that is not, or will not be used for any of the above purposes in 3.1.1–3.1.4. Such software may be acquired (including commercial off the shelf (COTS)) or designed software. Examples of this software include personal productivity software (e.g., Microsoft PowerPoint, Oracle Project Primavera, MS Outlook, etc.) and other types of software (e.g., some business accounting systems, facility personnel comfort temperature monitoring systems). This is non-safety software and is categorized as Commercially Controlled software. Proceed to **Part 5.** Part 4 is not required. Provide supporting comments (as required). MCNP is a general-purpose Monte Carlo N-Particle code that can be used for neutron, photon, electron, or coupled neutron/photon/electron transport. Specific areas of application include, but are not limited to, radiation protection and dosimetry, radiation shielding, radiography, medical physics, nuclear criticality safety, Detector Design and analysis, nuclear oil well logging, Accelerator target design, Fission and fusion reactor design, decontamination and decommissioning. The code treats an arbitrary three-dimensional configuration of materials in geometric cells bounded by first- and second-degree surfaces and fourth-degree elliptical tori. Though it is used for help in the analysis of a facility by the safety personnel, it is not directly connected to the analysis, design, or support of a facility. Also, MCNP would not stop work if it was unavailable. The listing in the ADX coop is to identify the importance and priority of backup functionality.

Part 4: Determine the Software Risk Level (SRL).	
4.1	Complete this section for safety software and risk significant software only. Do not complete this section for commercially controlled software. Check **only one** of the following to determine the SRL. Text shown in *[brackets]* is applicable to safety software only.
SRL 1 ☐	4.1.1 This level includes software applications that meet one or more of the following criteria. Failure of the software could: ▪ *[Compromise a limiting condition for operation].* ▪ *[Cause a reduction in the safety margin for a safety SSC that is cited in a DOE approved documented safety analysis.]* ▪ Cause a reduction in the safety margin for other systems such as toxic or chemical protection systems that are cited in either (a) a DOE approved documented safety analysis or (b) an approved hazard analysis per DOE P 450.4A, *Integrated Safety Management Policy*, and the DEAR ISMS clause (48 CFR 970.5223-1, *Integration of Environment, Safety, and Health into Work Planning and Execution*). ▪ Result in non-conservative safety analysis, design, or misclassification of facilities or SSCs. Provide supporting comments (as required).
SRL 2 ☐	4.1.2 This level includes *[safety]* software applications that do not meet SRL 1 criteria, but meet one or more of the following criteria: ▪ *[Safety management databases used to aid in decision making whose failure could impact safety SSC operation.]* ▪ Software failure that could result in incorrect analysis, design, monitoring, alarming, or recording of hazardous exposures to workers or the public. ▪ *[Software failure could compromise the defense-in-depth capability for a nuclear (including radiological) facility.]* Provide supporting comments (as required).
SRL 3 ☐	4.1.3 This level includes software applications that do not meet SRL 2 criteria, but meet one or more of the following criteria. Failure of the software could: ▪ Cause a potential violation of regulatory permitting requirements. ▪ Affect environment, safety, health monitoring, or alarming systems. ▪ Affect the safe operation of an SSC. Provide supporting comments (as required).

Part 5: Attest to compliant completion, review and approve. A signature is required in 5.1, 5.2 and 5.3 for all completed 2033 Forms.

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5.1 As the Software Owner (SO), I have determined the software type, category, and as appropriate, SRL, in accordance with P1040, *Software Quality Management* and the instructions associated with this form. Provide Name/Z No. (print). Avneet Sood/150745	Signature Avneet Sood Digitally signed by Avneet Sood DN: c=US, o=U.S. Government, ou=Department of Energy, ou=Los Alamos National Laboratory, ou=People, serialNumber=150745, cn=Avneet Sood Date: 2018.06.21 13:48:44 -06'00'	Date
5.2 As the Software Owner Responsible Line Manager (SO RLM or SRLM), I have reviewed and approve the determination of the software type, category and, as appropriate, SRL for the software as described on this form. Provide Name/Z No. (print). Avneet Sood/150745	Signature Avneet Sood Digitally signed by Avneet Sood DN: c=US, o=U.S. Government, ou=Department of Energy, ou=Los Alamos National Laboratory, ou=People, serialNumber=150745, cn=Avneet Sood Date: 2018.06.21 13:49:00 -06'00'	Date
5.3 As the ☐ Facility Design Authority Representative (FDAR) for my representative facilities, as the ☐ LANL Design Authority (DA), or, as the ☒ Responsible Associate Director (RAD), I have reviewed and approve the determination of the software type, category and, as appropriate, SRL for the software as described on this form. Check one. Provide Name/Z No. (print). Michael Bernardin/099579 **Note:** The RAD is authorized to review and approve Form 2033 (rather than the FDAR or DA) for software applications where, **as determined by the FDAR or DA**, the FDAR or DA does not have the knowledge and/or a reasonable connection to the software.	Signature	Date

Supporting Comments Continuation Page

As needed, use this space to provide supporting comments. Provide the Form section number that corresponds to the comments.

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Appendix B

2018 MCNP, WRS-FORM-0001U (2 pages)

ADX Software Impact Grading Form **WRS-FORM-0001U**
Revision B
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Section 1: Software Information

1.1 Software Name or Code Family:	MCNP	**1.2 Version (can be blank if using Code Family):**	
1.3 Software Description:			
Monte Carlo Neutron and Photon transport code on solid body geometries and unstructured meshes.			

Section 2: Reasonable Probability (select one)

☐ Software does not have the reasonable probability of being **Safety or Risk Significant Software** (refer to P1040).

☑ Software may have reasonable probability of being **Safety or Risk Significant Software** (refer to P1040). Complete Form 2033 and submit as a record.

Section 3: Scoring

Factors/Score		**1**	**2**	**3**
3.1 Consequence of the Failure of the Software to meet Specification (Select one from each row)	**3.1.1**	☐ Unlikely or implausible safety, security or environmental impacts.	☑ Minimal safety, environmental or security concerns.	☐ Severe injury, illness or death; permanent environmental damage or a security breach.
	3.1.2	☐ Unlikely funding loss and negligible adverse organizational publicity.	☑ Possible loss of funding and/or adverse regional publicity.	☐ Likely loss of significant funding and/or adverse national publicity.
	3.1.3	☐ **Negligible delay (< 1 work day)** in production.	☑ **Delay (> 1 work day)** in production which results in scope or schedule creep and possible missed milestones	☐ **Stop** in production results in missed milestones, and adversely affects mission.

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ADX Software Impact Grading form

WRS-FORM-0001U
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Factors/Score		1	2	3
3.2 Complexity Of Software (select one from the row of software category)	3.2.1 New Designed	☐ Low to minimal complexity, few to no interfaces or separate code modules.	☐ Moderately Complex, multiple code modules and algorithms and interfaces.	☐ Highly complex system: numerous code modules, algorithms, interfaces, interconnection of subsystems and support software.
	3.2.2 Commercial Off the Shelf Software (COTS)	☐ Low complexity; has minimal features or requirements; Validation is not difficult; could be accomplished using calibration certificates or vendor provided test cases.	☐ Moderately complex with multiple modules and features; Test cases are moderately complex; validation could be accomplished using test cases provided by the vendor along with expert judgment and/or calculations.	☐ Highly complex specification; numerous code modules, algorithms, interfaces and support software. Test cases are complex; requires significant calculations or expert judgment to validate output.
	3.2.3 In-use Software	☐ Successfully tested, proven software solution and no modifications intended.	☐ Moderately Complex, minimal modifications, software is stable, and multiple stakeholders.	☑ Highly complex system, frequent modifications, and multiple stakeholders.
			3.3 Total Sum:	9
Section 4: Impact Level		☐ Low Impact (1-6)	☑ Medium Impact (7-9)	☐ High Impact (10-12)

Section 5: Approvals

Software Owner	*Date*	*Z number*
AVNEET SOOD Avt Sood	16 JULY 2018	150745
Software RLM	*Date*	*Z number*
Scott Doebling	8/2/18	818967

Released: 6/18/18