Pacific Northwest
NATIONAL LABORATORY

PNNL-35785

FAST-1.2.1 User Installation and Verification Guide

Developed Under NQA-1-2017

March 2024

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Prepared for the U.S. Nuclear Regulatory Commission
Office of Nuclear Regulatory Research
Under Contract DE-AC05-76RL01830
Interagency Agreement: 31310019N0001
Task Order Number: 31310019F0047

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Pacific Northwest National Laboratory
Richland, Washington 99354

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Approvals

Role	Name	Signature	Date
Code Custodian	David Colameco	David V Colameco Digitally signed by David V Colameco Date: 2024.03.26 10:04:42 -07'00'	
Lead Software Developer	Ken Geelhood	Kenneth J (Ken) Geelhood Digitally signed by Kenneth J (Ken) Geelhood Date: 2024.03.26 11:10:07 -07'00'	
Project Manager	Katie Wagner	Katie A Wagner Digitally signed by Katie A Wagner Date: 2024.03.26 12:18:54 -07'00'	

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Introduction

The purpose of this document is to provide the user information about the installation of Fuel Analysis for Steady state and Transient (FAST)-1.2.1 on their computers or servers. General information about the code and supported operating systems is described in Section 1.0. Self-service oriented FAST-1.2.1 software licensing steps are described in Section 2.0. An installation verification test suite is provided with FAST-1.2.1 and described in Section 3.0. A convenience script for converting Fuel Rod Analysis Program – Constant (FRAPCON) to FAST inputs is discussed in Section 4.0.

FAST-1.2.1 was developed and released under a software quality assurance program based upon NQA-1-2017 at Pacific Northwest National Laboratory (PNNL). FAST-1.2.1 is the latest baseline code. The installation verification test suite contains both steady state and transient Anticipated Operation Occurrences (AOOs), accident conditions, such as Reactivity Initiated Accidents (RIAs) and Loss of Coolant Accidents (LOCAs).

Acronyms and Abbreviations

AOO	Anticipated Operational Occurrences
ASME	American Society of Mechanical Engineers
FAST	Fuel Analysis for Steady state and Transient
FGR	Fission Gas Release
FRAPCON	Fuel Rod Analysis Program – CONstant
hash	Hash Function used to map data of an arbitrary size to fixed-size values.
LOCA	Loss of Coolant Accident
LWR	Light Water Reactor
NRC	United States Nuclear Regulatory Commission
NQA-1	Nuclear Quality Assurance – 1
MD5	Widely used 128-bit message-digest hash value for uniquely identifying files.
PNNL	Pacific Northwest National Laboratory
POC	Point of Contact
QA	Quality Assurance
QAP	Quality Assurance Plan
RIA	Reactivity Initiated Accident
SHA-1	Widely used 160-bit message-digest hash value for uniquely identifying files.

Definitions

This Section provides definitions specific to the software project.

Assessment	A review, evaluation, inspection, test, check, surveillance, or audit to determine and document whether items, processes, systems, or services meet specified requirements and perform effectively. (NQA-1-2017)
Acceptance Testing	The process of exercising or evaluating a system or system component by manual or automated means to ensure that it satisfies the specific requirements and to identify differences between expected and actual results in the operating environment. (NQA-1-2017)
Configuration Item	A collection of hardware or software elements treated as unit for the purpose of configuration control. (NQA-1-2017)
Configuration Management (software)	The process of identifying and defining the configuration items in a system (i.e. software and hardware), controlling the release and change of those items throughout the system's life cycle, and recording and reporting the status of configuration items and change requests. (NQA-1-2017)
Baseline	A specification or product that has been formally reviewed and agreed upon, that thereafter serves as the basis for use and further development, and that can be changed only by using an approved control process. (NQA-1-2017)
Error	A condition deviating from an established baseline, including deviations from the current approved computer program and its baseline requirements. (NQA-1-2017)
Confluence	Confluence is an easy-to-use web-based tool that is utilized for electronically documenting software in a wiki format. Documents can also be controlled. It offers the ability to document, collaborate, and share.
Graded Approach	The process of ensuring that the level of analysis, documentation, and actions used to comply with a requirement is commensurate with: a) the relative importance to safety, safeguards, and security b) the magnitude of any hazard involved c) the life-cycle stage of a facility or item d) the programmatic mission of a facility e) the particular characteristics of a facility or item f) the relative importance of radiological and nonradiological hazards g) any other relevant factors (NQA-1-2017)
HDI	A web search engine that houses PNNL's Lab-level requirements and procedures and considerations for conducting work. The content is delivered via graphical workflows (step-by-step flowcharts with steps for each activity), through narrative work controls (listing of requirements and considerations for managing specific risks and hazards), or in forms or exhibits (linked documents that include greater detail).
Independent	(Independent Reviews or Independent Testing) Person sufficiently independent with respect to the material/product they are reviewing/testing; they did not perform the work they are reviewing or testing. Staff also possess enough subject matter expertise to adequately review/test/evaluate.
Operating Environment	A collection of software, firmware, and hardware elements that provide for the execution of computer programs. (NQA-1-2017)

Software Design Verification	The process of determining if the product of the software design activity fulfills the software design requirements. (NQA-1-2017)
Software Engineering	(a) The application of a systematic, disciplined, quantifiable approach to the development, operation, and maintenance of software; that is, the application of engineering to software. (b) The study of approaches in (a) (NQA-1-2017)
Test Case	A set of test inputs, execution conditions, and expected results developed for a particular objective, such as to exercise a particular program path or to verify compliance with a specific requirement. (NQA-1-2017)
Test Plan (Procedure)	A document that describes the approach to be followed for testing a system or component. Typical contents identify items to be tested, tasks to be performed, and responsibilities for the testing activities. (NQA-1-2017)
Verification	Mathematical proof of the correctness of algorithms, by confirming that code subroutines and functions produce the expected numerical output.
Validation	The process of evaluating software to determine whether it satisfies specified requirements, by comparing code predictions to experimental data.
Unit test	Process or code developed to test the numeric accuracy and functionality of new or modified subroutines and functions.
Unit test suite	Set of unit tests created while developing and maintaining FAST.
Verification test suite	Set of input files that exercise all the code options, used to verify that code changes do not negatively impact code performance, and that results are as expected.
Validation test suite	Set of input files used to validate the codes' predictions against experimental measurements, to quantify the accuracy, bias, and uncertainty of code predictions.

Contents

Figures

Tables

1.0 General Software Information

FAST-1.2.1 has been compiled on Windows 11 and Red Hat Enterprise Linux 7.9 operating systems. The compiled executables in Table 1 were then tested on Windows and Linux operating systems listed in Table 2 using the test suites available in Section 3.0. FAST is not currently supported on MacOS.

Table 1 – FAST-1.2.1 Executable Identification

Executable	OS	Hash
FAST-1.2.1.exe	Windows	MD5 746b7e40bc5a8f29b66c8a04216a42bd SHA-1 0e6bbff62a03bfa64d466eb0efb55745e89dd0dc
FAST-1.2.1	Linux	MD5 b7bb18a834b3652477d38be04dbaff2b SHA1 ce668002b0ef73a4ab5b51870e7249456cf88aad

Due to the large variety of operating systems available to our users' group, not all possibilities can be tested. The list in Table 2 is an attempt to provide wide coverage of currently supported systems: Windows and Linux. If your installation on a current operating system not listed below results in larger than expected differences or difficulties, please contact PNNL (see website contact information) and we will attempt to identify and correct/mitigate the issue. The list in Table 2 below is comprehensive enough that unforeseen difficulties with installation should be rare.

Table 2 – FAST-1.2.1 Tested Operating Systems

Operating System	Version	Comments
Windows 10 Enterprise	22H2	OS Build 19045.2006
Windows 11 Enterprise	23H2	OS Build 22631.2428
Windows 11 Pro for Workstations	23H2	OS Build 22631.3296
Windows Server Standard 2019	1809	OS Build 17763.3650
Windows Server Standard 2022	21H2	OS Build 20348.587
Debian Bookworm	12.5	Linux Kernel 6.1.0-18-amd64
Fedora Workstation	39.0	Linux Kernel 6.7.9-200.fc39.x86_64
openSUSE Leap	15.5	Linux Kernel 5.14.21-150500.55.52-default
Red Hat Enterprise Linux	7.9	Linux Kernel 3.10.0-1160.105.1.el7.x86_64
Rocky	9.3	Linux Kernel 5.14.0-362.24.1.el9_3.x86_64

1.1 Acquiring the Software

The FAST website is https://fast.labworks.org. The website contains limited information for visitors not logged in but more documentation and access to the software for logged in visitors. Visitors without log in credentials may apply using the "Join Us" tab on the homepage.

The Codes tab on the homepage lists the codes available for download, FAST-1.2.1, FAST-1.2 FRAPCON-4.0 and FRAPTRAN-2.0. This document will focus on FAST-1.2.1. Follow the link to FAST-1.2.1 and download the zip or tgz file that is applicable to your target machine's file decompression software. Typically, Windows users would choose the zip file while Linux users can decompress either zip or tgz files with preinstalled software. MacOS is not currently supported.

The following hash values are associated with the zip and tgz files along with the text file listing of the contents. The zip and tgz files contain identical contents.

Table 3 – FAST-1.2.1 File Identification

File	OS	Hash
FAST-1.2.1.zip	Windows/Linux	MD5 40db5a1928c7158c4b3c72fe6bcaeb92 SHA-1 4bbc72407ee80a9f0da2870a013f1645b2e0fabf
FAST-1.2.1.tgz	Windows/Linux	MD5 989cf54b4ca6fffba0ac64dfd028b29d SHA1 0968b064974bc416b56361c0258eaf1e7f25b685
md5sum_listing	Windows/Linux	MD5 6922de52c9c13cbe3637593569418697 SHA1 975f81fa9c2fbbf4d4bb8e464d77dc669ef47c6c
sha1sum_listing	Windows/Linux	MD5 75b6c21cfdc169487cd4b4a8a318ea77 SHA1 a1e0dd8441c26486e0335c28460ea439c9265f5e

The Linux command `tar -xzvf FAST-1.2.1.tgz` will decompress the folder. The FAST-1.2.1.zip and FAST-1.2.1.tgz files have the same contents described in Table 4 below:

Table 4 – FAST-1.2.1 File Identification

Folder	Description
Convenience_Scripts	Python 3 conversion script, AIG, FRAPlot (See Section 4.0)
Installation_Verification	Installation Verification Tests (See Section 3.0)
Linux_Executable	Linux Executable
Linux_FAST_Licensing	Linux Licensing software (See Section 2.0)
Windows_Executable	Windows Executable
Windows_FAST_Licensing	Windows Licensing software (See Section 2.0)

These next steps are primarily for users needing to establish traceability from the identification in Table 1 and 3 above to the final installation location on their machines. These steps may also be used to verify that the executable file was not corrupted during the download and/or transfer process to the final location.

Once the executable and associated files are installed on your target machine, the SHA-1 or MD5 should be checked and compared to Table 1 and Table 3. Other, more secure, hashing algorithms are available such as SHA-2 however it is assumed that MD5 and/or SHA-1 will provide the user confidence the executable was not altered in the download/transfer process. Users that require hashes such as SHA-2 are encouraged to contact PNNL through the website.

Windows offers a pre-installed utility CertUtil and a downloadable utility FCIV available on the support.microsoft.com website. The pre-installed utility will be demonstrated here. Open a command prompt and navigate to the location of your executable or provide the path of the executable. Then execute the command: `CertUtil -hashfile FAST-1.2.exe SHA1` (or `MD5` in place of SHA1) as shown in Figure 1:

```
C:\Users\cola105\Downloads>CertUtil -hashfile FAST-1.2.1.exe md5
MD5 hash of FAST-1.2.1.exe:
746b7e40bc5a8f29b66c8a04216a42bd
CertUtil: -hashfile command completed successfully.

C:\Users\cola105\Downloads>CertUtil -hashfile FAST-1.2.1.exe sha1
SHA1 hash of FAST-1.2.1.exe:
0e6bbff62a03bfa64d466eb0efb55745e89dd0dc
CertUtil: -hashfile command completed successfully.
```

Figure 1: Window's CertUtil Hashing Example

Linux offers md5sum and sha1sum command line utilities as demonstrated in Figure 2 below:

```
cola105@we39393 ~
$ md5sum FAST-1.2.1
b7bb18a834b3652477d38be04dbaff2b *FAST-1.2.1

cola105@we39393 ~
$ sha1sum FAST-1.2.1
ce668002b0ef73a4ab5b51870e7249456cf88aad *FAST-1.2.1
```

Figure 2: Linux md5sum and sha1sum Example

A matching md5 or sha1 hash provides a very high likelihood that the executables were not corrupted during the download and transfer to the final location on the target machine. If the hashes do not match, try downloading FAST from the website again. Changes to the files change the hash values.

The location of the FAST executable on your target machine depends largely on preferences and your organizations rules or guidelines. The installation verification that is described in Section 3.0 can be performed on your target machine by updating the associated python script.

Linux users may have to install libgfortran.so.5 via the sudo [apt-get, yum, zipper] libgfortran5 for newer linux operating systems, or by installing gcc-12 for older systems to provide needed libraries.

2.0 Self-Service Licensing

Installations of FRAPCON 4.0 and FRAPTRAN 2.0 do not require these licensing steps.

A successfully copied FAST-1.2.1 executable in the target location of the target computer must now be licensed for it to operate. Licensing has been set up as self-service through the FAST website https://fast.labworks.org and the page https://fast.labworks.org/fast_license. Figure 3 below shows the website after clicking the “Codes” tab highlighted in a red box.

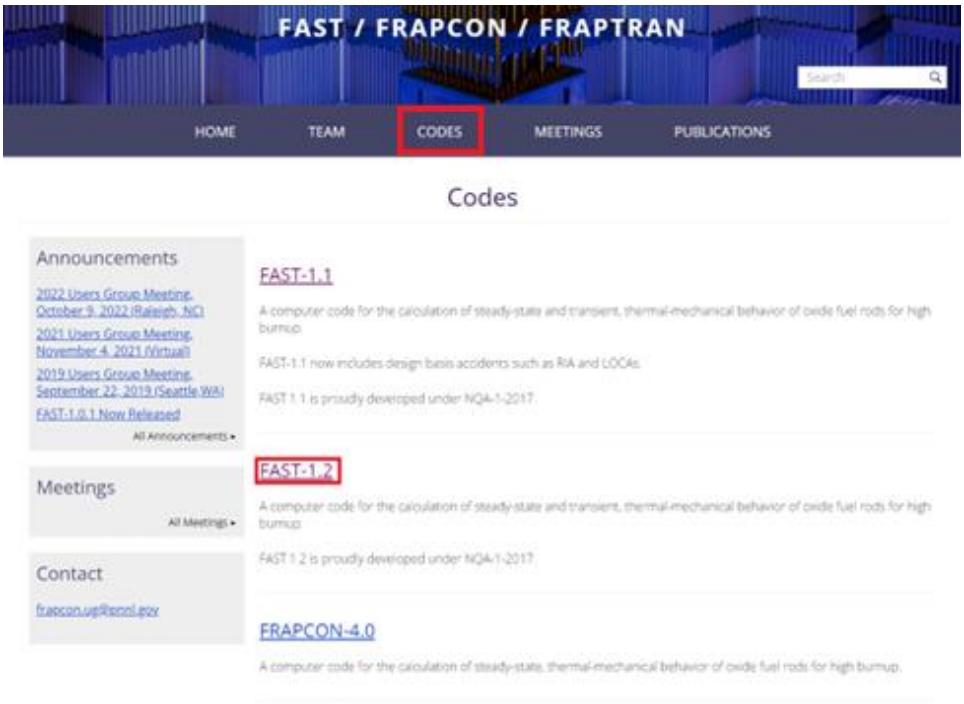

Figure 3: FAST Website FAST-1.2.1 Link Location

The link “FAST-1.2.1” in Figure 3 above will take you to the FAST-1.2.1 screen in Figure 4 below.

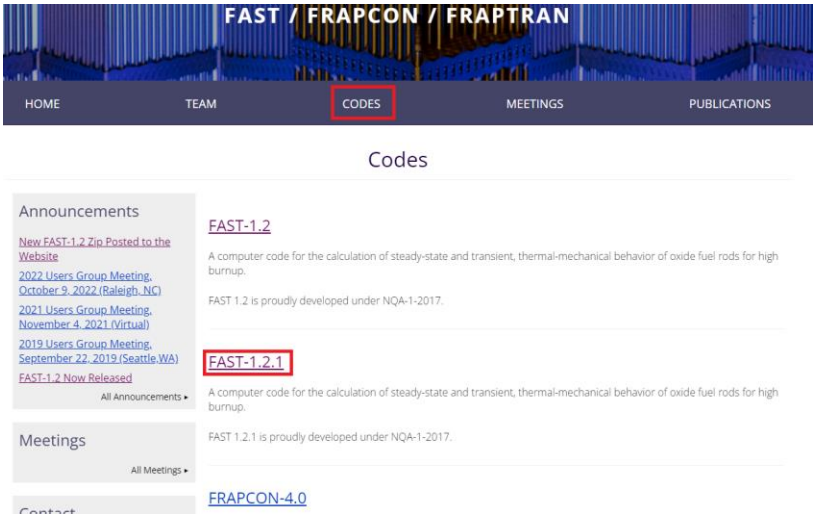

Figure 4: FAST Website Licensing Link Location

The link “FAST License Generation” in Figure 4 above will take you to the FAST License Generator screen in Figure 5 below.

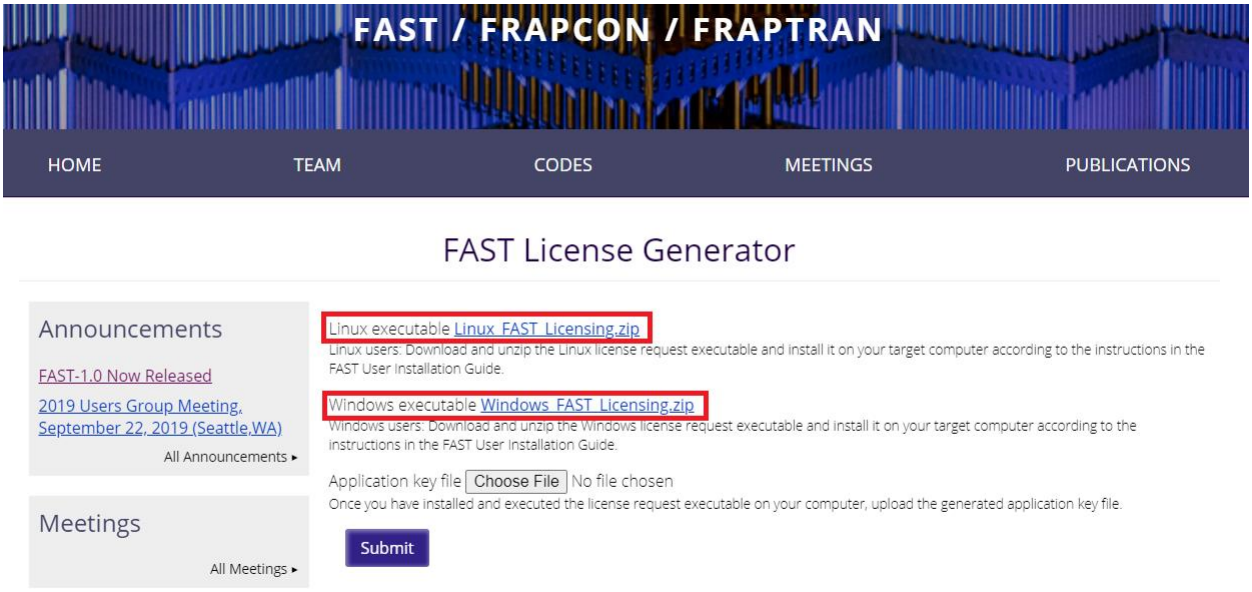

Figure 5: FAST Licensing Webpage

First select the appropriate licensing for the target machine’s OS: Linux or Windows highlighted in red boxes in Figure 5. MacOS is currently not supported. There is a limit of 5 license files per website user. If you need more licenses, please contact PNNL through the website e-mail.

With the `CreateLicenseRequestFile(.exe)` on the target machine, execute the program as shown in Figures 6 and 7 depending upon your target machine’s operating system.

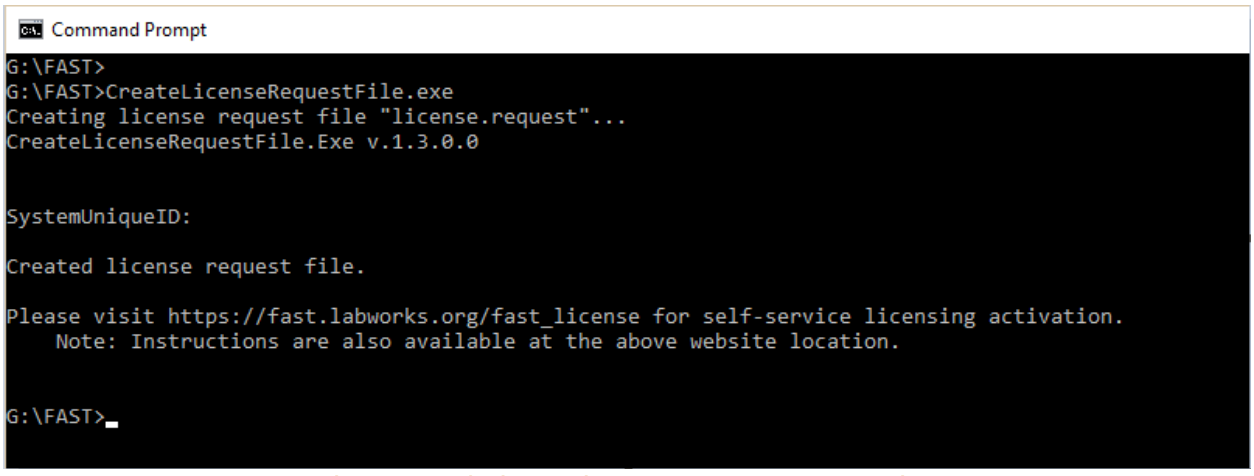

Figure 6: Windows License Request Generation

```
                Test]$ ./CreateLicenseRequestFile
Creating license request file "license.request"...
CreateLicenseRequestFile.Exe v.1.3.0.0


SystemUniqueID:

Created license request file.

Please visit https://fast.labworks.org/fast_license for self-service licensing activation.
    Note: Instructions are also available at the above website location.

[               Test]$
```

Figure 7: Linux License Request Generation

A file named “license.request” is generated. Select “Choose File.”

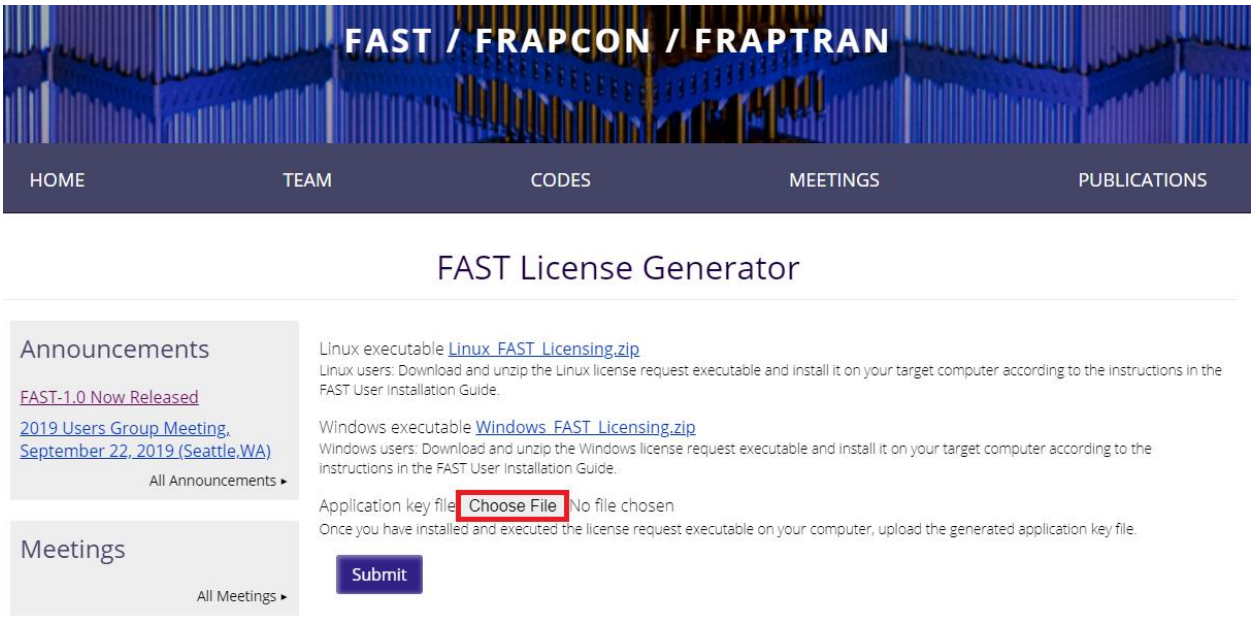

Figure 8: FAST License Request Website File Selection

Clicking “Choose File” highlighted in Figure 8 opens a File Explorer in Windows and a File Manager in Linux. Once a license.request file is selected, its name will appear to the right of the “Choose File” Icon as seen in Figure 9 below. Do not change the name of the license.request file before uploading it. Click the “Submit” button which is also highlighted in red to create a FASTProduct.key.

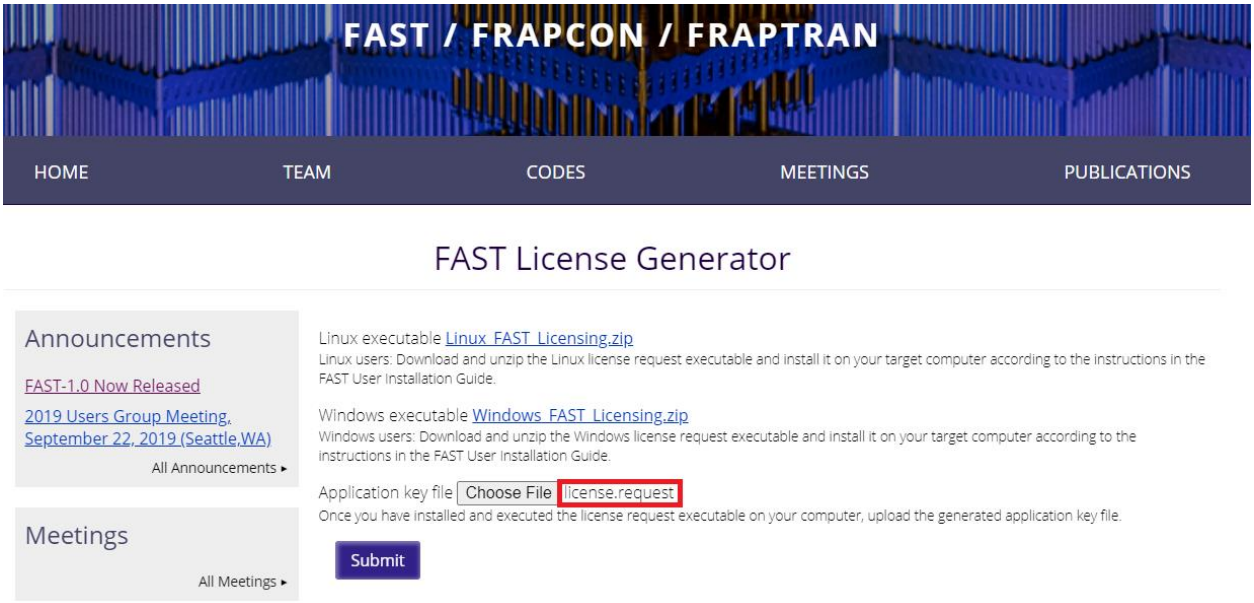

Figure 9: FAST License Request Website Submission

Clicking “Submit” generates the FASTProduct.key which shows up as a download link as highlighted in Figure 10 below. Download this file and place it in the same directory as the FAST execution on your target machine. Please do not change the name of this FASTProduct.key file. Your installation of FAST-1.2.1 is now complete and ready for verification testing in Section 3.0. It may be necessary to “right-click” the FASTProduct.key and choose “Save as”.

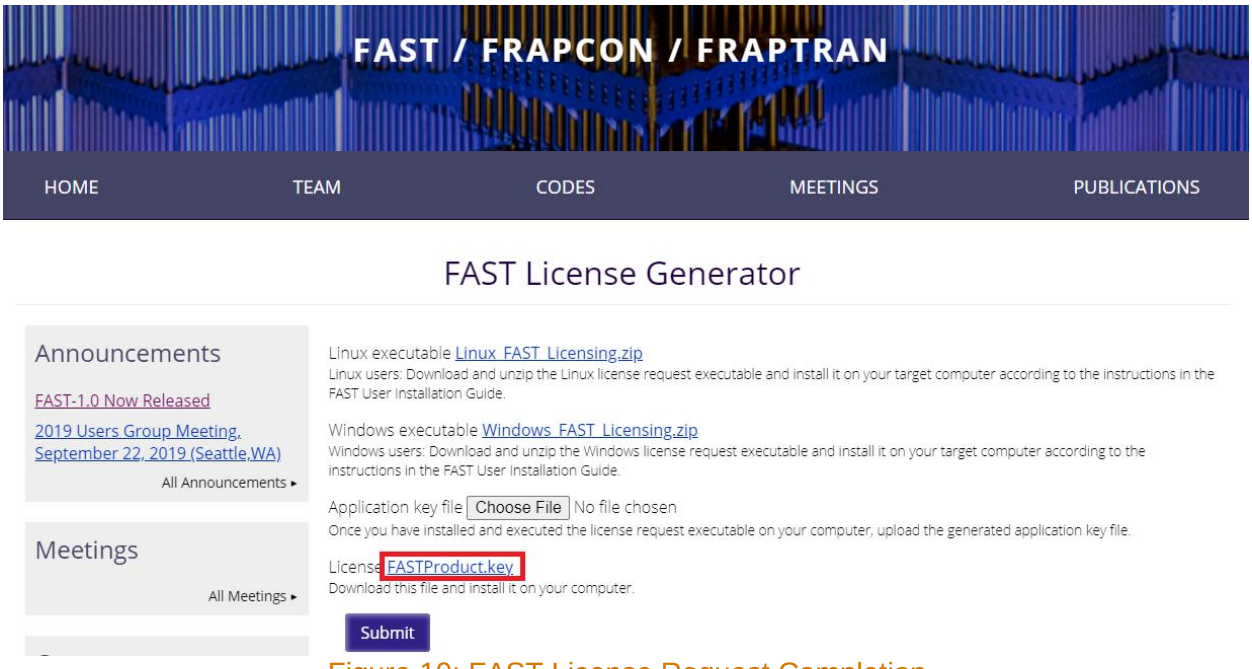

Figure 10: FAST License Request Completion

3.0 Installation Verification Suite

Now that your copy of FAST-1.2.1 has been downloaded and installed on the target machine in the target location (Section 1.0) and a FASTProduct.key (Section 2.0) has been obtained, the installation test suite can be executed. The FASTProduct.key must be in the location where you are running FAST-1.2 (where the outputs are generated). Typically, the user will run FAST-1.2.1 in a manner where the FAST-1.2.1 outputs are generated in the same location as the FAST-1.2.1 inputs by typing FAST-1.2.1 and the input file on the command line. The verification script keeps the inputs and outputs separate as a convenience to the user. The FASTProduct.key must be placed in the User_Verification_Outputs folder prior to executing the verification script.

This section will describe the test suite and the steps to execute the testing automation script. The script verification_diff.py is written in Python 3 and used with Python 3.12.2 (as of January 2020 Python 2 was frozen and will no longer be developed). The script will execute the set of supplied FAST-1.2.1 inputs and provided files with the extension ".diff" that contain the differences between the FAST-1.2.1 output files generated on your machine and the output files generated by the FAST development team.

Use of a Python version other than 3.6 to 3.12 is possible; it is up to the person performing the testing to ensure that the diff files reflect the differences in output files. This can be done by spot checking a diff file and its associated files.

Tests included in the Verification Suite are listed in Table 5 below.

Table 5 – FAST Verification Suite Tests

File Name	Test Name	Comments
FGR_BWstudR1.in	FGR_BWstudR1	B&W Studsvik Rod 1 for predicted fission gas release.
Oxide_N05.in	Oxide_N05	N05 Case for predicted oxide thickness.
Strain_GE7.in	Strain_GE7	GE7 Case for permanent hoop strain following a power ramp.
Temperature_681-3.in	Temperature_681-3	IFA-681 Rod 3 for predicted fuel centerline temperature.
Temperature_ifa_432r3.in	Temperature_ifa_432r3	IFA-432 Rod 3 for predicted fuel centerline temperature.
Void_24i6.in	Void_24i6	24i6 case for predicted end of life rod void volume.

To execute the Verification Suite first download and transfer the compressed file to the target machine. The verification_diff.py script must be updated if the FAST-1.2.1 executable is installed in a location other than that of the folder structure described in Table 4.

3.1 Expected Differences

The differences listed in this section were generated from machines which are less than 5 years old. Differences in architecture may result in round off error. The user is invited to use their professional judgement or contact PNNL via the website contact information for interpretation of larger than expected differences.

Sample difference files are included in the Installation_Verification/Sample_Difference_Files/ folder. The testing conducted at PNNL using virtual machines and physical machines showed that the verification_diff.py script only shows file names and minor rounding. The script ignores expected differences in execution dates, usernames, and computer names. When Linux and Windows outputs are compared it was found that the peak axial node in a flat power profile changed but the fuel performance values remained the same.

Please see the Sample_Difference_Files folder for text files with differences. See Appendix A for a Windows difference file listing. The following is a listing of the Debian Bookworm 12.5 differences, where some rounding occurs in the Temperature case, using Python 3:

```
****************************************************************************************************************
*********
|FGR_BWstudR1|

+++ /media/sf_D_Shared_Folder/Debian_Bookworm/FAST-
1.2.1/Installation_Verification/Verification_Cases/Outputs/FGR_BWstudR1
--- /media/sf_D_Shared_Folder/Debian_Bookworm/FAST-
1.2.1/Installation_Verification/User_Verification_Outputs/FGR_BWstudR1

+++ line:244
--- line:244
################################################################################################################
#########


****************************************************************************************************************
*********
|Oxide_N05|

+++ /media/sf_D_Shared_Folder/Debian_Bookworm/FAST-
1.2.1/Installation_Verification/Verification_Cases/Outputs/Oxide_N05
--- /media/sf_D_Shared_Folder/Debian_Bookworm/FAST-
1.2.1/Installation_Verification/User_Verification_Outputs/Oxide_N05

+++ line:346
--- line:346
################################################################################################################
#########


****************************************************************************************************************
*********
|Strain_GE7|

+++ /media/sf_D_Shared_Folder/Debian_Bookworm/FAST-
1.2.1/Installation_Verification/Verification_Cases/Outputs/Strain_GE7
--- /media/sf_D_Shared_Folder/Debian_Bookworm/FAST-
1.2.1/Installation_Verification/User_Verification_Outputs/Strain_GE7

+++ line:427
--- line:427
################################################################################################################
#########


****************************************************************************************************************
*********
|Temperature_681-3|

+++ /media/sf_D_Shared_Folder/Debian_Bookworm/FAST-
1.2.1/Installation_Verification/Verification_Cases/Outputs/Temperature_681-3
```

```
--- /media/sf_D_Shared_Folder/Debian_Bookworm/FAST-
1.2.1/Installation_Verification/User_Verification_Outputs/Temperature_681-3

+++ line:286
--- line:286
+++ line:3758    local linear heat rating, kW/m(kW/ft)     9.14(   2.78)           rod surface heat flux,
W/m**2(btu/hr-ft**2)   3.06E+05( 9.71E+04)
--- line:3715    local linear heat rating, kW/m(kW/ft)     9.14(   2.79)           rod surface heat flux,
W/m**2(btu/hr-ft**2)   3.06E+05( 9.71E+04)
+++ line:3840    local linear heat rating, kW/m(kW/ft)     9.14(   2.78)           rod surface heat flux,
W/m**2(btu/hr-ft**2)   3.06E+05( 9.71E+04)
--- line:3796    local linear heat rating, kW/m(kW/ft)     9.14(   2.79)           rod surface heat flux,
W/m**2(btu/hr-ft**2)   3.06E+05( 9.71E+04)
+++ line:3922    local linear heat rating, kW/m(kW/ft)     9.14(   2.78)           rod surface heat flux,
W/m**2(btu/hr-ft**2)   3.06E+05( 9.71E+04)
--- line:3877    local linear heat rating, kW/m(kW/ft)     9.14(   2.79)           rod surface heat flux,
W/m**2(btu/hr-ft**2)   3.06E+05( 9.71E+04)
+++ line:9526    local linear heat rating, kW/m(kW/ft)    15.08(   4.59)           rod surface heat flux,
W/m**2(btu/hr-ft**2)   5.05E+05( 1.60E+05)
--- line:9413    local linear heat rating, kW/m(kW/ft)    15.08(   4.60)           rod surface heat flux,
W/m**2(btu/hr-ft**2)   5.05E+05( 1.60E+05)
+++ line:9527    peak  linear heat rating, kW/m(kW/ft)    15.08(   4.59)
--- line:9414    peak  linear heat rating, kW/m(kW/ft)    15.08(   4.60)
+++ line:9608    local linear heat rating, kW/m(kW/ft)    15.08(   4.59)           rod surface heat flux,
W/m**2(btu/hr-ft**2)   5.05E+05( 1.60E+05)
--- line:9494    local linear heat rating, kW/m(kW/ft)    15.08(   4.60)           rod surface heat flux,
W/m**2(btu/hr-ft**2)   5.05E+05( 1.60E+05)
+++ line:9609    peak  linear heat rating, kW/m(kW/ft)    15.08(   4.59)
--- line:9495    peak  linear heat rating, kW/m(kW/ft)    15.08(   4.60)
+++ line:9690    local linear heat rating, kW/m(kW/ft)    15.08(   4.59)           rod surface heat flux,
W/m**2(btu/hr-ft**2)   5.05E+05( 1.60E+05)
--- line:9575    local linear heat rating, kW/m(kW/ft)    15.08(   4.60)           rod surface heat flux,
W/m**2(btu/hr-ft**2)   5.05E+05( 1.60E+05)
+++ line:9691    peak  linear heat rating, kW/m(kW/ft)    15.08(   4.59)
--- line:9576    peak  linear heat rating, kW/m(kW/ft)    15.08(   4.60)
+++ line:9773    peak  linear heat rating, kW/m(kW/ft)    15.08(   4.59)
--- line:9657    peak  linear heat rating, kW/m(kW/ft)    15.08(   4.60)
+++ line:9855    peak  linear heat rating, kW/m(kW/ft)    15.08(   4.59)
--- line:9738    peak  linear heat rating, kW/m(kW/ft)    15.08(   4.60)
+++ line:9937    peak  linear heat rating, kW/m(kW/ft)    15.08(   4.59)
--- line:9819    peak  linear heat rating, kW/m(kW/ft)    15.08(   4.60)
+++ line:10019    peak  linear heat rating, kW/m(kW/ft)    15.08(   4.59)
--- line:9900    peak  linear heat rating, kW/m(kW/ft)    15.08(   4.60)
+++ line:10101    peak  linear heat rating, kW/m(kW/ft)    15.08(   4.59)
--- line:9981    peak  linear heat rating, kW/m(kW/ft)    15.08(   4.60)
+++ line:10183    peak  linear heat rating, kW/m(kW/ft)    15.08(   4.59)
--- line:10062    peak  linear heat rating, kW/m(kW/ft)    15.08(   4.60)
+++ line:24358    local linear heat rating, kW/m(kW/ft)    21.24(   6.47)           rod surface heat flux,
W/m**2(btu/hr-ft**2)   7.12E+05( 2.26E+05)
--- line:24065    local linear heat rating, kW/m(kW/ft)    21.24(   6.48)           rod surface heat flux,
W/m**2(btu/hr-ft**2)   7.12E+05( 2.26E+05)
+++ line:24440    local linear heat rating, kW/m(kW/ft)    21.24(   6.47)           rod surface heat flux,
W/m**2(btu/hr-ft**2)   7.12E+05( 2.26E+05)
--- line:24146    local linear heat rating, kW/m(kW/ft)    21.24(   6.48)           rod surface heat flux,
W/m**2(btu/hr-ft**2)   7.12E+05( 2.26E+05)
+++ line:24522    local linear heat rating, kW/m(kW/ft)    21.24(   6.47)           rod surface heat flux,
W/m**2(btu/hr-ft**2)   7.12E+05( 2.26E+05)
--- line:24227    local linear heat rating, kW/m(kW/ft)    21.24(   6.48)           rod surface heat flux,
W/m**2(btu/hr-ft**2)   7.12E+05( 2.26E+05)
+++ line:32602   2   22.3    1    0.18    1.15  464.0  468.5  472.9  2.79  553.9  607.6  648.7     0.0  -1949.8
-1175.0  0.1200  0.32398      563.4  294.5   0.0   0.00   10.4
--- line:32209   2   22.3    3    0.18    1.15  464.0  468.5  472.9  2.79  553.9  607.6  648.7     0.0  -1949.8
-1175.0  0.1200  0.32398      563.4  294.5   0.0   0.00   10.4
+++ line:32603   3   53.0    3    0.63    2.02  464.0  471.9  479.7  2.46  602.6  696.6  763.8     0.0  -1775.7
-1093.5  0.1197  0.32462      651.7  318.1   0.0   0.01   11.3
--- line:32210   3   53.0    1    0.63    2.02  464.0  471.9  479.7  2.46  602.6  696.6  763.8     0.0  -1775.7
-1093.5  0.1197  0.32462      651.7  318.1   0.0   0.01   11.3
+++ line:32607   7   93.3    1    1.49    3.48  464.2  477.6  491.1  2.09  666.9  844.8  968.3     0.0  -1456.8
-944.2  0.1213  0.32533      784.6  361.7   0.0   0.02   12.9
--- line:32214   7   93.3    3    1.49    3.48  464.2  477.6  491.1  2.09  666.9  844.8  968.3     0.0  -1456.8
-944.2  0.1213  0.32533      784.6  361.7   0.0   0.02   12.9
+++ line:32610  10  123.5    3    2.26    3.76  464.3  478.8  493.3  1.94  669.3  874.4 1018.2     0.0  -1361.8
-899.8  0.1206  0.32564      846.7  374.6   0.0   0.03   14.4
--- line:32217  10  123.5    1    2.26    3.76  464.3  478.8  493.3  1.94  669.3  874.4 1018.2     0.0  -1361.8
-899.8  0.1206  0.32564      846.7  374.6   0.0   0.03   14.4
+++ line:32611  11  136.2    6    2.66    4.32  464.4  481.0  497.7  1.84  687.1  932.8 1107.9     0.0  -1220.0
-833.4  0.1218  0.32586      903.1  393.9   0.0   0.03   15.2
--- line:32218  11  136.2    1    2.66    4.32  464.4  481.0  497.7  1.84  687.1  932.8 1107.9     0.0  -1220.0
-833.4  0.1218  0.32586      903.1  393.9   0.0   0.03   15.2
+++ line:32618  18  176.9    1    4.12    5.57  464.7  486.2  507.6  1.56  712.9 1065.5 1333.0     0.0   -860.3
-665.0  0.1332  0.32644     1074.5  443.0   0.0   0.05   18.1
```

```
--- line:32225  18  176.9    6    4.12    5.57  464.7  486.2  507.6  1.56  712.9 1065.5 1333.0     0.0   -860.3
-665.0  0.1332  0.32644     1074.5  443.0   0.0   0.05   18.1
+++ line:32625  25  232.5    9    6.71    6.68  465.4  491.1  516.7  1.26  715.3 1191.8 1586.1     0.0   -422.8
-460.2  0.1414  0.32707     1333.3  502.6   0.1   0.08   23.1
--- line:32232  25  232.5    1    6.71    6.68  465.4  491.1  516.7  1.26  715.3 1191.8 1586.1     0.0   -422.8
-460.2  0.1414  0.32707     1333.3  502.6   0.1   0.08   23.1
+++ line:32633  33  295.6    9   10.00    7.59  466.3  495.4  524.5  0.97  699.4 1340.0 1937.1     0.0    191.7
-172.5  0.1596  0.32771     1719.1  586.1   0.1   0.12   29.4
--- line:32240  33  295.6    1   10.00    7.59  466.3  495.4  524.5  0.97  699.4 1340.0 1937.1     0.0    191.7
-172.5  0.1596  0.32771     1719.1  586.1   0.1   0.12   29.4
+++ line:32635  35  314.4    1   11.00    7.52  466.5  495.4  524.2  0.96  696.3 1334.5 1928.4     0.0    206.2
-165.7  0.1623  0.32774     1730.5  587.9   0.1   0.13   31.3
--- line:32242  35  314.4    9   11.00    7.52  466.5  495.4  524.2  0.96  696.3 1334.5 1928.4     0.0    206.2
-165.7  0.1623  0.32774     1730.5  587.9   0.1   0.13   31.3
+++ line:32636  36  321.9    3   11.41    7.52  466.6  495.5  524.3  0.95  695.6 1335.8 1930.9     0.0    217.9
-160.2  0.1635  0.32776     1739.2  589.7   0.1   0.14   32.1
--- line:32243  36  321.9    1   11.41    7.52  466.6  495.5  524.3  0.95  695.6 1335.8 1930.9     0.0    217.9
-160.2  0.1635  0.32776     1739.2  589.7   0.1   0.14   32.1
+++ line:32637  37  331.5    6   11.94    7.55  466.8  495.7  524.7  0.94  694.2 1340.6 1940.3     0.0    250.9
-144.8  0.1653  0.32779     1765.1  594.1   0.1   0.14   33.2
--- line:32244  37  331.5    1   11.94    7.55  466.8  495.7  524.7  0.94  694.2 1340.6 1940.3     0.0    250.9
-144.8  0.1653  0.32779     1765.1  594.1   0.1   0.14   33.2
+++ line:32679 x           Axial node                =          4         x
--- line:32286 x           Axial node                =          1         x
##########################################################################################################################
#########


**************************************************************************************************************************
*********
|Temperature_ifa-432r3|

+++ /media/sf_D_Shared_Folder/Debian_Bookworm/FAST-
1.2.1/Installation_Verification/Verification_Cases/Outputs/Temperature_ifa-432r3
--- /media/sf_D_Shared_Folder/Debian_Bookworm/FAST-
1.2.1/Installation_Verification/User_Verification_Outputs/Temperature_ifa-432r3

+++ line:265
--- line:265
##########################################################################################################################
#########


**************************************************************************************************************************
*********
|Void_24i6|

+++ /media/sf_D_Shared_Folder/Debian_Bookworm/FAST-
1.2.1/Installation_Verification/Verification_Cases/Outputs/Void_24i6
--- /media/sf_D_Shared_Folder/Debian_Bookworm/FAST-
1.2.1/Installation_Verification/User_Verification_Outputs/Void_24i6

+++ line:294
--- line:294
##########################################################################################################################
#########
```

3.2 FAST-1.2.1 Code Change Requests

NQA-1-2017 is a more rigorous quality assurance program, however issues with code may arise. Please use the form in Appendix B to request changes and e-mail it to PNNL via the contact information on the FAST website.

4.0 Convenience Scripts

A convenience script that converts FRAPCON input to FAST input is included. FAST-1.2.1 performs calculations for normal operations and AOOs. FRAPTRAN initialized with FRAPCON will be used for design basis accidents such as RIAs and LOCAs. The convenience script contains preliminary conversions for standalone FRAPTRAN inputs however the FAST-1.2.1 code is only for normal operations and AOOs.

4.1 Execution of FRAPCON_to_FAST.py

The Python3 script FRAPCON_to_FAST_Inputs.py will convert FRAPCON inputs to FAST inputs. The script retains the order of the variables from the FRAPCON input in the FAST input for easier comparisons. Changes to Fortran NAMELIST block beginnings and endings are included for compliance with the latest Fortran standards. The previous files used Intel formatting which can be slightly different from the general Fortran standard. The user of the script will find indices added to arrays and comments added for each variable. Please note that the FRAPCON input file can only have one instance of each NAMELIST block to properly work.

Execution of the script is best performed in a new directory with input files containing the ending with ".in". The script will convert FRAPCON files by writing a new file with the ending _FAST.in. Executing the command `python3 FRAPCON_to_FAST_Inputs.py all` will convert all files in the working directory. Executing the command `python3 FRAPCON_to_FAST_Inputs.py 24i6.in` will only convert the file name given to 24i6_FAST.in.

4.2 FAST-1.2.1 AIG

The Microsoft Excel-based tool for generating input, developed for use with the FAST codes is FAST-1.2.1 AIG. This auto input-generator is similar to the AIG for FRAPCON and FRAPTRAN but with differences for FAST.

4.3 FRAPlot

The Microsoft Excel-based tool for plotting developed for use with the FAST codes is FRAPlot. Instructions for its use are located in Appendix C, Section C.3, in FAST-1.2.1: A Computer Code for Thermal-Mechanical Nuclear Fuel Analysis under Steady-state and Transients, PNNL-35701.

5.0 References

The following documents were utilized to develop and/or are referenced in this document:

- 10 CFR, Title 10 Code of Federal Regulations, United State Government, 2018.
- ASME NQA-1-2017, Quality Assurance Requirements for Nuclear Facility Applications, January 18, 2018.
- DOE G 414.1-4, Safety Software Guide for use with 10 CFR 830 Subpart A, Quality Assurance Requirements, and DOE O 414.1C, Quality Assurance, November 2010.
- NRC NUREG/BR-0167 Software Quality Assurance Program and Guidelines, February 1993.
- PNNL-35701, FAST-1.2.1: A Computer Code for Thermal-Mechanical Nuclear Fuel Analysis under Steady State and Transients, Revision 0, March 2024.

Appendix A – Windows Server 2019 Standard Differences

The following difference is a comparison of Windows Server 2019 Standard with files run on Windows 11. Only the file names are written to the .txt file. Rounding may occur with your setup depending upon hardware architecture.

```
**********************************************************************************************************************
*********
|FGR_BWstudR1|

+++ Z:\Windows_Server_Standard_2019\FAST-
1.2.1\Installation_Verification/Verification_Cases/Outputs/FGR_BWstudR1
--- Z:\Windows_Server_Standard_2019\FAST-1.2.1\Installation_Verification/User_Verification_Outputs/FGR_BWstudR1

######################################################################################################################
#########


**********************************************************************************************************************
*********
|Oxide_N05|

+++ Z:\Windows_Server_Standard_2019\FAST-1.2.1\Installation_Verification/Verification_Cases/Outputs/Oxide_N05
--- Z:\Windows_Server_Standard_2019\FAST-1.2.1\Installation_Verification/User_Verification_Outputs/Oxide_N05

######################################################################################################################
#########


**********************************************************************************************************************
*********
|Strain_GE7|

+++ Z:\Windows_Server_Standard_2019\FAST-1.2.1\Installation_Verification/Verification_Cases/Outputs/Strain_GE7
--- Z:\Windows_Server_Standard_2019\FAST-1.2.1\Installation_Verification/User_Verification_Outputs/Strain_GE7

######################################################################################################################
#########


**********************************************************************************************************************
*********
|Temperature_681-3|

+++ Z:\Windows_Server_Standard_2019\FAST-
1.2.1\Installation_Verification/Verification_Cases/Outputs/Temperature_681-3
--- Z:\Windows_Server_Standard_2019\FAST-
1.2.1\Installation_Verification/User_Verification_Outputs/Temperature_681-3

+++ line:32617  17  169.9    9    3.84    5.33  464.6  485.1  505.7  1.61  708.8 1039.9 1287.9     0.0   -933.5
-699.3  0.1316  0.32633     1038.7  433.1   0.0   0.05   17.5
--- line:32617  17  169.9    1    3.84    5.33  464.6  485.1  505.7  1.61  708.8 1039.9 1287.9     0.0   -933.5
-699.3  0.1316  0.32633     1038.7  433.1   0.0   0.05   17.5
+++ line:32619  19  182.2    9    4.34    5.74  464.8  486.9  509.0  1.52  715.9 1084.9 1366.6     0.0   -805.8
-639.5  0.1343  0.32652     1099.9  450.5   0.0   0.05   18.5
--- line:32619  19  182.2    1    4.34    5.74  464.8  486.9  509.0  1.52  715.9 1084.9 1366.6     0.0   -805.8
-639.5  0.1343  0.32652     1099.9  450.5   0.0   0.05   18.5
+++ line:32622  22  199.7    9    5.12    6.58  465.0  490.3  515.6  1.35  724.6 1167.2 1518.3     0.0   -546.8
-518.3  0.1388  0.32688     1247.4  485.5   0.0   0.06   20.0
--- line:32622  22  199.7    1    5.12    6.58  465.0  490.3  515.6  1.35  724.6 1167.2 1518.3     0.0   -546.8
-518.3  0.1388  0.32688     1247.4  485.5   0.0   0.06   20.0
+++ line:32623  23  207.1    9    5.48    6.65  465.1  490.7  516.2  1.31  721.9 1176.2 1539.2     0.0   -508.5
-500.3  0.1396  0.32696     1280.5  491.0   0.0   0.07   20.7
--- line:32623  23  207.1    1    5.48    6.65  465.1  490.7  516.2  1.31  721.9 1176.2 1539.2     0.0   -508.5
-500.3  0.1396  0.32696     1280.5  491.0   0.0   0.07   20.7
+++ line:32625  25  232.5    9    6.71    6.68  465.4  491.1  516.7  1.26  715.3 1191.8 1586.1     0.0   -422.8
-460.2  0.1414  0.32707     1333.3  502.6   0.1   0.08   23.1
--- line:32625  25  232.5    1    6.71    6.68  465.4  491.1  516.7  1.26  715.3 1191.8 1586.1     0.0   -422.8
-460.2  0.1414  0.32707     1333.3  502.6   0.1   0.08   23.1
+++ line:32626  26  235.6    9    6.87    7.07  465.5  492.6  519.7  1.19  718.9 1230.2 1655.6     0.0   -301.8
-403.5  0.1431  0.32721     1405.3  519.0   0.1   0.08   23.4
--- line:32626  26  235.6    1    6.87    7.07  465.5  492.6  519.7  1.19  718.9 1230.2 1655.6     0.0   -301.8
-403.5  0.1431  0.32721     1405.3  519.0   0.1   0.08   23.4
+++ line:32633  33  295.6    9   10.00    7.59  466.3  495.4  524.5  0.97  699.4 1340.0 1937.1     0.0    191.7
-172.5  0.1596  0.32771     1719.1  586.1   0.1   0.12   29.4
```

```
--- line:32633  33  295.6    1   10.00    7.59  466.3  495.4  524.5  0.97  699.4 1340.0 1937.1     0.0    191.7
-172.5  0.1596  0.32771     1719.1  586.1   0.1   0.12   29.4
+++ line:32637  37  331.5    6   11.94    7.55  466.8  495.7  524.7  0.94  694.2 1340.6 1940.3     0.0    250.9
-144.8  0.1653  0.32779     1765.1  594.1   0.1   0.14   33.2
--- line:32637  37  331.5    1   11.94    7.55  466.8  495.7  524.7  0.94  694.2 1340.6 1940.3     0.0    250.9
-144.8  0.1653  0.32779     1765.1  594.1   0.1   0.14   33.2
+++ line:32679 x           Axial node                 =          4         x
--- line:32679 x           Axial node                 =          1         x
##########################################################################################################################
#########


**************************************************************************************************************************
*********
|Temperature_ifa-432r3|

+++ Z:\Windows_Server_Standard_2019\FAST-
1.2.1\Installation_Verification/Verification_Cases/Outputs/Temperature_ifa-432r3
--- Z:\Windows_Server_Standard_2019\FAST-
1.2.1\Installation_Verification/User_Verification_Outputs/Temperature_ifa-432r3

##########################################################################################################################
#########


**************************************************************************************************************************
*********
|Void_24i6|

+++ Z:\Windows_Server_Standard_2019\FAST-1.2.1\Installation_Verification/Verification_Cases/Outputs/Void_24i6
--- Z:\Windows_Server_Standard_2019\FAST-1.2.1\Installation_Verification/User_Verification_Outputs/Void_24i6

##########################################################################################################################
#########
```

Appendix B – FAST Change Request Form

The following form can e-mailed to PNNL via the FAST website contact information to request a change or report a software deficiency.

(select one) No. _____

(Assigned by PM)

1. RELEASED VERSION ID. _____
2. REQUESTOR _____ PHONE _____/_____
3. ERROR REPORTED: ☐ YES ☐ NO E-MAIL _____
4. PROJECTED START DATE: _____
5. ESTIMATED TIME FOR COMPLETION: _____
6. DESCRIPTION (attach continuation sheets if necessary)

7. REASON FOR MODIFICATION (attach continuation sheets if necessary)

8. CODE PERFORMANCE IMPACTS (If applicable)

To be completed by PM

ACTION: APPROVED DENIED DATE RECEIVED _____

ASSIGNED TO _____

Approval for new modification _____ Date _____

Pacific Northwest National Laboratory

902 Battelle Boulevard
P.O. Box 999
Richland, WA 99354
1-888-375-PNNL (7665)

www.pnnl.gov* | *www.nrc.gov