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## **Verification of the Prompt Radiation Shielding Design of the ESS Accelerator**

### **Cooperative Research and Development Agreement Final Report**

**CRADA Number: FRA-2015-0302**

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Summary Report  
December 1, 2016

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In accordance with Requirements set forth in Article XI.A(3) of the CRADA document, this document is the final CRADA report, including a list of Subject Inventions, to be forwarded to the Office of Science and Technical Information as part of the commitment to the public to demonstrate results of federally funded research.

**CRADA number:** FRA-2015-0302

**CRADA Title:** Verification of the Prompt Radiation Shielding Design of the ESS Accelerator

**Parties to the Agreement:** European Spallation Source, ESS ERIC and Fermi Research Alliance, LLC

**Abstract of CRADA work:**

Fermilab will perform prompt radiation and shielding verification studies for the European Spallation Source ERIC (ESS) accelerator tunnel and existing penetration layouts using the latest information on the beam line and existing models of magnets and cryomodels. The input information about the assumptions, geometry layout, etc. will be provided by the Safety Group (accelerator division, ESS). The MEDT department of the Accelerator Division, Fermilab will provide the results of the studies.

MARS15, a Fermilab a multi-purpose Monte-Carlo code developed since 1974, is at the heart of this effort. MARS15 is used for detailed simulation of hadronic and electromagnetic cascades in an arbitrary 3-D geometry of shielding, accelerator, detector and spacecraft components with energy ranging from a fraction of an electronvolt to 100 TeV. This work will provide additional validation of recent additions to the physical models in the code, including the code capabilities to simulate cascades and generate a variety of results in complex media.

**Summary of Research Results:**

Comprehensive studies with the MARS15(2016) Monte-Carlo code are described on evaluation of prompt and residual radiation levels induced by nominal and accidental beam losses in the 5-MW, 2-GeV European Spallation Source (ESS) Linac. These are to provide a basis for radiation shielding design verification through the accelerator complex. The calculation model is based on the latest engineering design and includes a sophisticated algorithm for particle tracking in the machine RF cavities as well as a well-established model of the beam loss. Substantial efforts were put in solving the deep-penetration problem for the thick shielding around the tunnel with numerous complex penetrations. It allowed us to study in detail not only the prompt dose, but also component and air activation, radiation loads on the soil outside the tunnel, and skyshine studies for the complicated 3-D surface above the machine. Among the other things,

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the newest features in MARS15 (2016), such as a ROOT-based beamline builder and a TENDL-based event generator for nuclear interactions below 100 MeV, were very useful in this challenging application

**Related Reports, Publications, and Presentations:**

Fermilab-Conf-16-543-APC, December 2016, "MARS15 SIMULATION OF RADIATION ENVIRONMENT AT THE ESS LINAC", N.V. Mokhov et al (OSTI Identifier 1340484)

**Subject Inventions listing:**

None

**Report Date:** December 1, 2016

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