

Memorandum of Understanding

Concerning

Cooperation in the Area of Radiation Damage In Accelerator Target Environments (the RaDIATE Collaboration)

This Memorandum of Understanding (MOU) is among Fermi National Accelerator Laboratory, Science and Technology Facilities Council, the Chancellor Masters and Scholars of Oxford University, Brookhaven National Laboratory, Pacific Northwest National Laboratory, Oak Ridge National Laboratory, Michigan State University, European Spallation Source – European Research Infrastructure Consortium (ESS-ERIC), Los Alamos National Laboratory, Argonne National Laboratory, Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (Center of Energy, Environmental and Technological Research), European Organization for Nuclear Research (CERN), High Energy Accelerator Research Organization (KEK), and Japan Atomic Energy Agency (JAEA), collectively referred to herein as the “Participants”.

DESIRING to cooperate on the response of materials to Radiation Damage In Accelerator Target Environments (RaDIATE), specifically that resulting from high energy particle beam interactions with matter; and

RECOGNIZING their mutual interest in those activities which develop a better understanding of radiation damage mechanisms and the associated thermal and mechanical properties response for materials of interest to future high power accelerator target facilities,

The Participants have reached the following understanding:

1.0 Planned Cooperation

Possible cooperation under this MOU includes, but is not limited to:

- 1.1 Materials under investigation:
 - 1.1.1 Polycrystalline fine-grained graphite
 - 1.1.2 Commercially available structural grades of beryllium
 - 1.1.3 Tungsten and high-density tungsten alloys
 - 1.1.4 Molybdenum and molybdenum alloys
 - 1.1.5 Carbon-Carbon composite materials
 - 1.1.6 Titanium alloys
 - 1.1.7 Austenitic stainless steels
 - 1.1.8 Tantalum
 - 1.1.9 Aluminium alloys
 - 1.1.10 Nickel-based super-alloys
 - 1.1.11 Ferritic-martensitic steels

- 1.1.12 Silicon
 - 1.1.13 Iridium
 - 1.1.14 Other target, beam window, and collimator candidate materials
- 1.2 Properties under investigation:
- 1.2.1 Thermal diffusion (heat capacity, conduction)
 - 1.2.2 Tensile properties (yield & ultimate strengths, elastic modulus, ductility)
 - 1.2.3 Fracture toughness
 - 1.2.4 Fatigue/Creep-fatigue
 - 1.2.5 Thermal expansion
 - 1.2.6 Dimensional stability (swelling, void formation) and irradiation creep
 - 1.2.7 In-situ and post-irradiation annealing characteristics
 - 1.2.8 General corrosion characteristics (weight loss)
 - 1.2.9 Microstructural evaluation
- 1.3 Typical irradiation environments under investigation (as appropriate for each material/application):
- 1.3.1 Particle energy (1 MeV – 7 TeV)
 - 1.3.2 Irradiation temperature (100 - 2000 C)
 - 1.3.3 Atmosphere (inert, vacuum, Low-humidity air, water)
 - 1.3.4 Displacements per atom (greater than 0.1 DPA)

2.0 Relationship to Other Programs

The subject areas cited in Section 1.0 may support elements of a coherent program that may include (but is not limited to):

- 2.1 Neutrino Super-beams (e.g. Long Baseline Neutrino Facility, Neutrino experimental facility at J-PARC)
- 2.2 Pulsed high-power proton source (Fermilab PIP-2) experimental facilities
- 2.3 The International Design Study for the Neutrino Factory
- 2.4 The Muon Collider Design Study
- 2.5 The potential future upgrades of the ISIS pulsed neutron source
- 2.6 The Facility for Rare Isotope Beams
- 2.7 The Spallation Neutron Source (SNS) First Target Station
- 2.8 The SNS Second Target Station
- 2.9 The European Spallation Source Target Station
- 2.10 LANSCE Isotope Production Facility
- 2.11 Lujan Scattering Facility
- 2.12 The International Fusion Materials Irradiation Facility (IFMIF)
- 2.13 The Intermediate Voltage Electron Microscope (IVEM)-Tandem Facility
- 2.14 The Extreme Materials Beamline (XMAT)
- 2.15 CERN's Large Hadron Collider (LHC)
- 2.16 CERN's Proton Synchrotron (PS) and Super Proton Synchrotron Complex and associated Fixed Target programs
- 2.17 Future Circular Collider (FCC) Study

- 2.18 The Materials and Life science experimental Facility (MLF) at J-PARC
- 2.19 The Hadron Experimental Facility (HEF) at J-PARC
- 2.20 Design study for the Transmutation Experimental Facility (TEF) Project at J-PARC

3.0 Forms of Cooperation

- 3.1 Short- and long-term visits to each other's facilities, subject to appropriate written arrangements
- 3.2 Exchange of publicly available information
- 3.3 Conduct of workshops, seminars, and other meetings.

4.0 General Considerations

- 4.1 This MOU establishes a framework for organizing and executing the RaDIATE program via a multi-institutional collaboration. The general organizing principles of the collaboration include the following:
 - 4.1.1 Fermi National Accelerator Laboratory intends to coordinate the RaDIATE program, including through the appointment of the Program Manager.
 - 4.1.2 The Program Manager is to oversee execution of the RaDIATE program. This includes organization of the program activities, development of schedules, preparation of periodic progress reports, and coordination of future program activities. The Program Manager is to deal directly with individual Participants on program matters.
 - 4.1.3 A Collaboration Council is to be created to advise and assist the Program Manager in the area of inter-institution coordination. The Collaboration Council is to consist of representatives, one designated by each Participant, who are to act as contact persons to whom correspondence is to be addressed.
- 4.2 This MOU does not create any legally binding obligations between or among the Participants.
- 4.3 Each Participant is to be responsible for the costs it incurs in participating in cooperative activities under this MOU.
- 4.4 Cooperative activities under this MOU may commence upon signature by the Participants and continue for a 5-year period unless earlier discontinued in accordance with Section 4.5.

- 4.5 The Participants may discontinue this MOU at any time in writing by mutual consent. A Participant that wishes to discontinue its participation in the activities contemplated by this MOU should endeavor to provide the other Participants at least 30 days written prior notice. This MOU may be modified by the mutual consent of all Participants in writing.
- 4.6 Each Participant should conduct the cooperation under this MOU in accordance with applicable laws and regulations to which it is subject, and international agreements to which its Government is a party.
- 4.7 Upon mutual written consent, the Participants may invite additional organizations to participate in cooperative activities conducted under this MOU.
- 4.8 The conduct of cooperative activities contemplated by this MOU is subject to the availability of funding, personnel, and other resources.
- 4.9 This MOU supersedes the Memorandum of Understanding Concerning Cooperation in the Area of Radiation Damage In Accelerator Target Environments signed May 15, 2015.

Signed in thirteen originals.

A handwritten signature or set of initials, possibly 'R.K.', enclosed within a hand-drawn triangular shape.

For Fermi National Accelerator Laboratory:



Nigel Lockyer
Laboratory Director



Date: 12/11/17
Place: Batavia



For Science and Technology Facilities Council:



24 Oct 17.

Andrew Taylor
Executive Director
National Laboratories

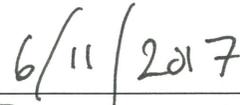
Date:
Place: Didcot



For The Chancellor Masters and Scholars of the University of Oxford:



Professor Patrick Grant
Head of Department of Materials



Date:
Place: Oxford



For Brookhaven National Laboratory:



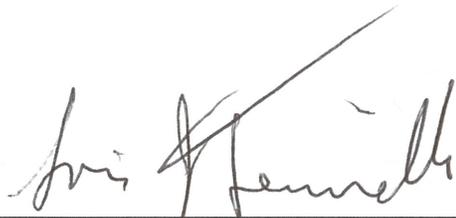
Doon Gibbs
Laboratory Director

11/3/17

Date:
Place: Upton



For Pacific Northwest National Laboratory:



10/19/17

Louis Terminello
Associate Laboratory Director for
Physical and Computational Sciences

Date:
Place: Richland



For Oak Ridge National Laboratory:

Paul Langan
Paul Langan
Associate Laboratory Director
Neutron Sciences Directorate

10/3/17
Date:
Place: Oak Ridge

PL

For Michigan State University:



Evonne Pedawi
Director, Contract and Grant Administration

Date: 31 Aug 2017
Place: East Lansing

OFFICE OF THE
GENERAL COUNSEL



APPROVED AS TO
FORM

8/31/2017
DATE



For European Spallation Source – ERIC (ESS):

W. J. Womersley

John Womersley
Director General

Date: 2017-09-07
Place: Lund

[Handwritten initials]

For Los Alamos National Laboratory:



Charles F. McMillan
Laboratory Director

11/14/17

Date:
Place: Los Alamos



For Argonne National Laboratory:

Matt Tirrell

11/3/17

Matt Tirrell
Deputy Laboratory Director for Science

Date:
Place: Lemont

RT

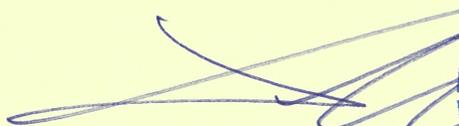
For Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas:

D. Ramón Gavela
Director General

Date: 14 NOV. 2017
Place: Madrid



For European Organization for Nuclear Research (CERN):


Frédéric Bordry
Director for Accelerators and Technology

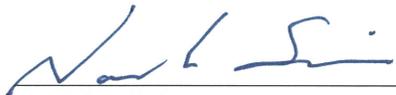


29/09/2017

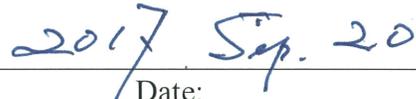
Date:
Place: Geneva



For
High Energy Accelerator Research Organization and Japan Atomic Energy Agency:



Naohito Saito
Director of J-PARC Center



Date:
Place: Tokai-mura

