February 24, 2016

United States Nuclear Regulatory Commission
Fuel Cycle Facilities Branch
Division of Fuel Cycle safety and Safeguards
Office of Nuclear Material Safety and Safeguards
Washington, D.C. 20555-0001

Attention: Tyrone D. Naquin, CHP
NMSS/FCSE/FMB

RE: Renewal of MIT SNM License-986

Attached please find the renewal application for the MIT SNM-986 license. There have been no changes in the use of licensed material during the past 10 years. The majority of the inventory remains in secured storage within the restricted area of our Nuclear Reactor Laboratory. An annual inventory of all licensed material is performed and reported to NMMSS. Most of the current licensed material inventory was transferred to MIT under DOE contracts and has been in storage for the past 20 years. We are working with our contracts department and their contacts at DOE to attempt to return or dispose of these stored materials. DOE has recently indicated there is potential to return the materials to Y-12.

Our current use of special nuclear material is limited. We use PuBe sources for detector calibrations, fission detectors for neutron detection, electro-deposited alpha sources for instrument calibration, solid/ liquid standards for instrument calibration, and foils in reactor experiments. Likewise, storage and use locations on the Cambridge campus are limited to the Nuclear Reactor Lab, the Plasma Science and Fusion Center, and several chemistry/analytical labs. At the Bates Linear Accelerator campus, we use a PuBe source for detector calibration and some natural uranium rods in accelerator experiments.

Our decommissioning funding plan has been updated to more accurately describe the future decommissioning/termination of license SNM-986. In addition, copies of our current financial assurance documents are enclosed in the application.

Please contact me if you have any questions or require additional information.

Thank you.

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Cambridge, Massachusetts 02139

Application to

U.S. NUCLEAR REGULATORY COMMISSION

for renewal of

SPECIAL NUCLEAR MATERIALS LICENSE NO. 986

Prepared February 24, 2016

By: ____________ Date: 2/25/2016
Mitchell S. Galanek, CHP
MIT Campus Radiation Protection Officer

By: ____________ Date: 2/25/16
William B. McCarthy, CHP
MITR Radiation Protection Officer

Approved by: ____________ Date: 2/25/16
Louis DiBerardinis, Director
Environment, Health, and Safety Office

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PART I - LICENSE CONDITIONS

Chapter 1: STANDARD CONDITIONS

1.1 Licensee's Name

Massachusetts Institute of Technology

1.2 Licensee's Address

77 Massachusetts Avenue; Room N52-496
Cambridge MA 02139

Correspondence concerning this license should be addressed to:

Mitchell Galanek
77 Massachusetts Avenue
N52-496
Cambridge, Massachusetts 02139

1.3 License Number

SNM-986; expiration date March 31, 2016

1.4 Types and quantities of materials authorized under SNM-986

A summary of the possession limit, locations of use, and types of material in use and in storage are outlined below. The maximum quantity of material that may be possessed and used is identified by isotope, enrichment, chemical and physical form, and mass in grams. Table 1 lists the maximum quantities of SNM that may be possessed by MIT under the license, SNM-986.

Table 1 - Possession Limits under SNM-986

Material	Form	Quantity
A. Uranium enriched to ≤ wt% in the U-235 isotope	A. U02 pellets, clad in steel, aluminum, or zircaloy	A.
B. Uranium enriched to ≤ wt% in the U-235 isotope	B. Metal or U02, slugs, foils, pellets and other shapes, clad	B.
C. Uranium enriched to ≤ wt% in the U-235 isotope	C. Metal or U02, solid slugs, foils, pellets and other shapes, unclad	C.
D. Uranium enriched to ≤ wt% in the U-235 isotope	D. Metal, U02 & other compounds and alloys, solid slugs, foils, fission chambers,	D.

	pellets, and other shapes clad and unclad, as laboratory solids and solutions	
E. Plutonium	E. Pu-Be neutron source and Pu-Al neutron filter	E.
F. Plutonium	F. Solid alpha source	F.
G. Plutonium	G. Solid, foils, pellets	G.
H. Natural uranium	H. Solid and solution	H.
I. Depleted uranium	I. Any	I.
J. Any byproduct material unseparated contained in any of the above	J. Unseparated	J. Quantities produced during irradiation
K. U-233	K. Solid	K.
L. Plutonium	L. Any	L.

The Institute shall not possess and use at any one time and location SNM in a quantity exceeding one effective kilogram of SNM except those uses involved in the operation of the MIT Research Reactor and as sealed sources.

1.5 Locations Where Material will be Stored/Used

The licensed special nuclear material and source material shall be used only at Institute facilities at the following locations:

a. MIT Campus and MIT Reactor, Cambridge MA
b. Bates Research and Engineering Center Line (Accelerator), Middleton,MA

1.6 Definitions

When used in this renewal application, terms defined in “Glossary of Terms in Nuclear Science and Technology" (American Nuclear Society Special Publication) and in Title 10 of the Code of Federal Regulations shall have the meanings given in those documents. In addition, the following definitions shall apply. Where documents are defined (items (c) through (f), the definition refers to the latest effective revision of the document.)

a. "Institute" or "MIT" means the Massachusetts Institute of Technology.

b. "MIT Research Reactor" and "MITR-II" refer to the reactor facility authorized under Nuclear Regulatory Commission Facility Operating License No. R-37.

c. "Technical Specifications" means the document [(1)] referred to in paragraph 2C(2) of Facility Operating License No. R-37, as amended.

d. "Safety Analysis Report" and "SAR" mean the document referred to in paragraph 2A of Facility Operating License No. R-37 and entitled "Safety Analysis Report for the MIT Research Reactor (MITR-II)", Report No. MITNE-115 (October 22, 1970), as amended.

e. "MIT Radioactive Material License" means License No. 60-0094, expiration date 9/30/2017, issued by the Massachusetts Department of Public Health, Radiation Control Program to MIT, as amended.

f. "Application for Radioactive Material License" means the application and supporting letter(s) (3) referenced in License No. 60-0094, as amended.

g. As stated in 10 CFR 70.4(t), "Effective kilograms of special nuclear material" means: (1) For plutonium and uranium-233, their weight, in kilograms; (2) For uranium with an enrichment in the isotope U-235 of 0.01 (1%) and above, its element weight in kilograms multiplied by the square of its enrichment expressed as a decimal weight fraction; and (3) For uranium with an enrichment in the isotope U-235 below 0.01 (1%), its element weight in kilograms multiplied by 0.0001.

h. "Reactor site" means the reactor containment building, the surrounding fenced-in lot and parking area, and the adjacent MIT building NW12. It is shown in Figure I.2-2.

1.7 <u>Authorized Activities</u>

Experience with SNM under the current and previous licenses over the past 30 years has shown that the current radiation protection programs which include routine reviews of material usage and audits is adequate to assure health and safety and to comply with license and regulatory requirements, particularly in view of the relatively small quantities of SNM actively in use at any particular location or time. As shown in this application, the activities at the Institute in no way resemble those at a uranium fuel fabrication plant.

Activities of the following types have been and will be performed utilizing the materials possessed under License No. SNM-986. Any irradiation in or experimental use on the MIT Reactor of materials possessed under this license shall be authorized under Facility Operating License No. R-37(1) and shall be subject to review and approval in advance in accordance with MITR-II Technical Specification 6.1 of License No. R-37(1). In such cases, storage and handling before and after use on the reactor shall be according to the conditions of this License No. SNM-986. Applications for proposed uses of materials elsewhere at the Institute are reviewed by the Campus Radiation Protection Program and further reviewed and approved/authorized by the Radiation Protection Committee through the authorization process described in the material license, 60-0094.

1.7.1 Alpha Sources

The electrodeposited Pu alpha sources will be used by or under the supervision of the Reactor, Bates, and Campus Radiation Protection programs for instrument calibration or for classroom demonstration of alpha detection.

1.7.2 Use in Fission Chambers

The highly enriched U-235 (HEU) in Item B fission chambers is used for the detection and measurement of neutrons generator in the reactor or the Plasma Science and Fusion Center (PSFC). There are currently 12 fission chambers at the PSFC containing approximately g of HEU in total.

1.7.3 Use of Neutrons Generated by SNM

The PuBe source use for instrument calibration will be done only at the reactor RPP facility and the Bates Linac facility. All calibrations will be done under the supervision of the Radiation Protection Programs.

1.7.4 Neutron Irradiations and Flux Measurements

Measurements of the neutron flux spatial and/or energy distribution is periodically required in reactor irradiation facilities. Also, foil irradiation is done in these same facilities for the purpose of creating calibration sources with fission spectra. The only the materials listed for such purposes are foils of Items D, G and L.

1.7.5 Use of Depleted Uranium for Shielding

The high density of uranium makes it useful for gamma ray shielding, particularly where it is desirable to minimize the shielding volume, and it is currently being so used for two purposes at the Institute. In neutron spectrometers, pieces of depleted uranium (Item I) have been machined to fit into small volumes as shielding for gamma rays emanating from the reactor core and from regions of high neutron capture in the beam ports. It is also used in three shipping containers because it provides more effective shielding than the lead which would otherwise fill a similar volume in the containers (Item K). In the latter case, steel encapsulation prevents spread of uranium contamination that otherwise might result from handling of the

shielding, but there is no handling once the spectrometer shielding is in place, and so in those cases a protective cladding of aluminum is adequate to preclude the release of uranium oxide formed on the surface of the blocks

1.7.6 Laboratory Solids and Solutions

Items B, H, L and K include enriched, normal, and depleted uranium and plutonium that are used in various forms, both solid and liquid. Depleted or enriched uranium and plutonium are used as "spikes" for calibrating analyses of geological specimens. There can be a variety of research and teaching uses for small amounts of the above materials. Activities involving only these small quantities (< grams) on SNM of low strategic significance can safely be conducted on the basis of the reviews performed by the Radiation Protection Program health physics staff and the review and authorization by the MIT Radiation Protection Committee.

1.7.7 Possession for Purposes of Storage and Disposition Only

The materials listed in the table below are securely stored in the NRL BTF vault. We continue to work at returning the material to DOE or disposing of material through a licensed low level waste disposal contractor. Consequently, those quantities in excess of our use requirements are being held only for storage and ultimate disposition. An annual inventory of material is performed and reported to the Nuclear Materials Management and Safeguards System (NMMSS) program by our Accountability Officer.

Storage of material is only within the restricted area of the _______________. We no longer store material in the campus Central Radioisotope Facility, room 6-017.

Description of how licensed materials are used.

The MIT uses SNM for research and training at various campus locations. The SNM and source material is only used at the following locations: the MIT Campus and MIT Reactor Lab, Cambridge MA and the Bates Research and Engineering Center, Middleton MA. Of the materials MIT is licensed to possess only a small fraction of that material is in actual use. Table 2 indicates the maximum expected use of materials and the locations.

Table 2 - Material Use and Locations			
Type of Use	Amount	Material Form	Location of use
fission chamber detectors	Max of _ grams per detector and total of __ grams	Contained source	MIT Research Reactor and MIT Campus (PSFC* only)
contained foils of uranium and/or plutonium for irradiation in the MIT research reactor	Max of __ g per foil and total of 10 grams each element	Foil contained in a quartz vial	MIT Research Reactor
Pu-Be neutron source for detector calibration	___ grams	Sealed Source	MIT Research Reactor Bates MIT Campus
Natural uranium slugs (Al clad) for use in shielding / radiation detection experiments	___ kg	Clad uranium metal	MIT Research Reactor Bates
Depleted uranium for shielding /radiation detection experiments	______ kg	Uranium metal	MIT Research Reactor
Uranium and plutonium in liquid form for the generation of calibration standards.	Max __ ug per isotope and total of _ g	Liquid calibration standards	MIT Campus MIT Research Reactor
Pu-239 check sources	__ ug total	Electroplated standard	MIT Campus MIT Research Reactor Bates
Storage of SNM	Per License Limit	Various Forms	MIT Research Reactor

* PSFC – Plasma Science and Fusion Center is a research lab on the MIT main campus.

There is no significant waste expected to be produced as part of the use of SNM since all of the current use of materials is only sealed or contained sources. Any use of liquid sources, based on past use, would likely be very small quantities and not produce very much waste. The DOE owns a significant amount of the material possessed by MIT and is obligated to take back the material. MIT is currently working with the DOE to return 99% of the material in our possession.

A more detailed description of activities for which the licensed material is used include the following:

1. Alpha sources: Electrodeposited plutonium alpha sources [Material F] are used on the MIT campus and at the Bates Linear Accelerator in the routine calibration of alpha detection devices used in health physics monitoring and radiation safety.
2. Use in fission chambers: Highly enriched U-235 [__ grams of Material D] is used for detection and measurement of neutrons generated in the MIT Reactor or Plasma Science and Fusion Center (PSFC) (an on-campus building). There are currently 12 fission chambers at the PSFC containing approximately __ grams of HEU in total.
3. Use of neutrons generated by SNM: Plutonium-beryllium encapsulated neutron sources [Material E] are used for calibration of neutron monitoring devices and for research purposes at the MIT reactor facility. Calibrations of neutron monitoring devices are also performed at the PSFC and the Bates Research and Engineering Center. All calibrations are performed by the radiation protection programs or under its supervision.
4. Laboratory solids and solutions: Enriched, natural, and depleted uranium and plutonium are used in various forms, both solid and liquid [Materials D, H, I and L]. Depleted or enriched uranium and plutonium are used as "spikes" for calibrating analyses of geological specimens. Migration of uranium and plutonium in soil with regards to decontamination of contaminated sites has been studied. Identification and characterization of unknowns in soils requires the use of uranium and plutonium standards. Research and teaching uses involving small quantities (<__ grams) of SNM of low strategic significance are reviewed by the Radiation Protection Program health physics staff and reviewed and authorized by the MIT Radiation Protection Committee.

5. Neutron irradiations and flux measurements of the neutron flux spatial and/or energy distribution is periodically required in reactor irradiation facilities. Also, foil irradiation is done in these same facilities for the purpose of creating calibration sources with fission spectra. The only the materials listed for such purposes are foils of Items D, G and L.

Possession of Licensed Material for Storage Only

In addition to the activities described in Section 1.7 of the license renewal, we have designated several of the licensed materials for storage only. These materials, and the quantity designated as storage only, are identified in Table 3 below:

Table 3. Materials Designated for Storage Only

Material	Quantity Designated as Storage Only
A. Uranium enriched to ≤_.0 wt% in the U-235 isotope	A. ____ grams of U-235
B. Uranium enriched to ≤_.0 wt% in the U-235 isotope	B. ____ grams of U-235
C. Uranium enriched to ≤_.0 wt% in the U-235 isotope	C. _____ grams of U-235
E. Plutonium	E. __ grams
G. Plutonium	G. ___ grams
H. Natural uranium	H. _____ kilograms
I. Depleted uranium	I. ___ kilograms
K. U-233	K. __ milligrams

Chapter 2 GENERAL ORGANIZATIONAL AND ADMINISTRATIVE REQUIREMENTS

2.1 Licensee's Policy

The MIT Policy on Environment, Health and Safety (EHS) is presented as follows:

> MIT is committed to excellence in environmental, health and safety stewardship on our campus, in the larger community of which we are a part, and globally. This long-held commitment is demonstrated through our contributions to environmental, health and safety research and teaching, as well as through our institutional conduct.
>
> MIT is committed to being at the forefront of large academic research institutions:
>
> - in minimizing, as feasible, the adverse environmental, health and safety impacts of our facilities, activities and operations to protect human health and the environment (which is one way we define sustainability);
> - in achieving and maintaining compliance with federal, state and local environmental, health and safety laws and good practices in all of our departments, laboratories, research centers, facilities and operations;
> - in achieving a high standard of institutional accountability for environmental, health and safety stewardship, while maintaining the independence of research and teaching;
> - in providing educational opportunities to our students and other members of our community, to reinforce the values exemplified in this policy and influence their activities during and after their tenure at MIT; and
> - in measuring and continuously improving our environmental, health and safety performance.

In pursuit of these general policies, the Institute has established the following safety committees, appointed by and reporting to the President of the Institute, to review and promulgate safety policies:

Institute Council on Environmental, Health, and Safety
Committee on Radiation Protection
Committee on Reactor Safeguards
Committee on Animal Care
Committee on Assessment of Biohazards
Committee on the Use of Humans as Experimental Subjects

Committee on Radiation Exposure to Human Subjects
Committee on Toxic Chemicals

The Committees on Radiation Protection and Reactor Safeguards in particular have responsibilities and authority in connection with the possession and use of materials authorized under this license, as described below in Section 2.3.

The policy that all organizational components shall keep radiation exposures to employees and to the general public as low as is reasonably achievable (ALARA) is set forth in MIT's Required Procedures for Radiation Protection, and in the MIT Reactor Procedures Manual, which specifies in the "Rules for Experiments and Maintenance Operations" that all radiation exposure are to be kept ALARA.

2.2 Organizational Responsibilities and Authority

Pursuant to the responsibilities of the Committees on Radiation Protection and on Reactor Safeguards, the lines of responsibility and authority of the Institute staff shall be as shown in the following Figure I.2-1.

The primary responsibility for safety shall rest with department, laboratory, or center's (DLC) head and their supervisory personnel (or Principal Investigator). The latter are shown as "Supervisor, Research Project" in the figure. The Director of Reactor Operations is also in this category.

Within the Environment Health and Safety Office, the Radiation Protection Officer who functions under the supervision of the Director of EHS, shall be "responsible for providing advisory and technical services necessary for the implementation of MIT's Radiation Protection Programs for both ionizing and non-ionizing radiation", including those sources held under this license and including the reactor. The MIT Reactor Radiation Protection Officer (MITR-RPO), who functions under the supervision of the Director of EHS, shall be responsible for such matters on the reactor site. The site consists of the reactor containment building, the surrounding fenced-in lot and parking area, and the adjacent MIT building NW12. It is depicted in Figure I.2-2. As indicated in Figure I.2-1, responsibility for radiation protection is entirely separate from that for utilization of radioactive materials.

The Criticality Officer in the Nuclear Reactor Laboratory (NRL) shall be responsible for providing advisory and technical services with regard to the use, storage, and shipping of SNM where criticality considerations are involved, as indicated in Figure I.2-1.

The organization chart also indicates the division of responsibilities with regard to the accounting for nuclear materials. The Accountability Officer in

NRL shall provide an accounting (at least annually) for all source and special nuclear materials held under this license. The MIT- Campus RPO is accountable for all radioactive material except that held under the MITR Facility Operating License, No. R-37, which is the responsibility of the Director of Reactor Operations.

2.3 Safety Review Committees

The two committees that have primary responsibilities for the safety review of utilization of the materials held under this license are the Reactor Safeguards Committee and the Radiation Protection Committee.

(a) Reactor Safeguards Committee (RSC)

The primary concern of this Committee is with matters of nuclear safety related to the MIT Research Reactor, including the safety of personnel on and off site. The Committee reviews and approves prior to implementation all new operating plans and policies, all significant modifications thereto, and all new experiments involving significant changes in procedure. The Committee verifies that nuclear reactor operation is consistent with MIT policy, rules, approved operating procedures, and license provisions.

The committee shall have responsibility for safety reviews, including criticality safety, of all utilization of materials under this license when the material is used on the reactor or when its use or storage within the reactor restricted area (Figure I.2-2) presents safety considerations with regard to the reactor. Most of the fissionable material and some of the source material fall into this category. Quantities of SNM outside the restricted area are limited to 10 CFR 70.24(a) amounts (see Section 4.1.4) and, hence, do not present criticality hazards. As radioactive material, however, such SNM is under the jurisdiction of the Radiation Protection Committee described in the following paragraph (b), as is source material not used in the reactor.

At least one member of the Reactor Safeguards Committee, other than the Criticality Officer, shall be qualified to evaluate nuclear criticality safety when the initial evaluation was prepared by the Criticality Officer. This member shall meet the minimum qualifications of the Criticality Officer.

The RSC performs its duties in accordance with the requirements of Technical Specification No. 7.5.2 of License No. R-37[(1)].

(b) Radiation Protection Committee (RPC)

This Committee is responsible for the establishment and continuing review of the radiation protection program at the Institute and its off-campus sites. The Committee is also responsible for the Institute's compliance with radiation protection regulations promulgated by state, Federal, and local agencies.

Further information relative to the responsibility, authority, and functioning of the RPC are given in Reference 3, Attachment #1.

The Radiation Protection Committee has promulgated requirements for the possession and use of radioactive materials in the form of Reference 3, Attachment #7. These are and shall be applicable to all locations including the reactor. The RPC reviews and approves all proposed possession and use of radiation sources except those on the reactor site. In special circumstances, such as where licensed material subject to the Institute's Radioactive Material License No. 60-0094, is to be used on the reactor site, it shall likewise review and approve such proposed uses.

2.4 Personnel Selection

The membership of both of the above committees is appointed by the MIT President.

Appointments to safety-related staff positions at the MIT Reactor are made by the Director of NRL and appointments in the Campus MIT and MITR Radiation Protection Programs are made by the Director of Environment, Health, and Safety Officer respectively.

2.5 Personnel Education and Experience Requirements

The minimum qualifications with regard to educational background and experience for the Director of Reactor Operations, Superintendent, MITR Radiation Protection Officer, Shift Supervisor and Reactor Operator shall be as specified in Technical Specification 7.3 of License No. R-37(1). The collective qualifications of the RSC shall be as prescribed by Technical Specification 7.5.2(e).

The minimum qualifications for the Criticality Officer or for the individual responsible for the nuclear criticality safety analyses, shall be an accredited college degree in physical sciences or engineering, plus a minimum of 3 years' nuclear safety experience. The nuclear experience shall include 1 year in outside-of-reactor nuclear criticality safety.

The minimum technical qualifications for the position of Radiation Protection Officer shall be a bachelor's degree in science or engineering, completion of

a basic radiation safety course, and at least 2 years of work experience in radiation protection. Certification by the American Board of Health Physics in the comprehensive practice of health physics shall be recognized as fulfillment of these qualifications.

The education and experience of Radiation Protection Program (RPP) staff members and the current membership of the RPC is described in Reference 3, Attachment #1 and #2.

2.6 Training

Licensed personnel at the MIT Reactor shall be trained and retrained in accordance with Section 1.16 of the MITR Procedure Manual, Qualification and Requalification Program. The program describes (1) a procedure for MITR Operator qualification, (2) a procedure for MITR Senior Operator/Shift Supervisor qualification and (3) a procedure for requalification of both classes of licensed personnel. The procedures for Operators requires completion of (a) a list of knowledge factors that include nuclear instrumentation, reactor physics, radiological controls, portable radiation detectors, radiation monitoring system, standard operating procedures, abnormal operating procedures, radiation emergency plan and others, (b) written quizzes covering the above areas and (c) completion of a list of practical factors related to the above. The procedure for Senior Operators/Shift Supervisors is similar but goes into greater depth in most areas and includes additional topics related to the reactor license, handling of reactor fuel, transport of radioactive material and others. The requalification procedure specifies on-the-job training in a number of areas such as the radiation emergency plan, review of the abnormal and emergency procedures, an annual written examination, further retraining if indicated, and a review board evaluation of each licensed individual every second year.

Training for individuals who are not licensed but who require access to the reactor facility for the conduct of experiments, such as use of materials covered by this license, or for some other reason, such as maintenance, shall receive training in the course of qualifying by radiation protection as a radiation worker and who requires unescorted access to the reactor and/or the adjacent exclusion area. Levels of qualification as a radiation worker is identified by a color code on the dosimetry devices issued.

Personnel involved with special nuclear material activities within the reactor restricted area shall receive appropriate criticality safety instruction.

Training for other individuals at MIT who do not require access to the Reactor but who use materials under this license shall be as required by Reference 3, Attachment #3.

Refresher training shall be provided to the Health Physics staff every 2 years, the same frequency used for authorized users. The records of the training shall be kept at least 5 years.

2.7 Operating Procedures

All use and storage of material under this license shall be in accordance with written procedures reviewed and implemented as follows:

2.7.1 Materials Involving the Reactor

For materials to be used on the reactor or for those to be used or stored within the reactor restricted area, the standard reactor administrative procedures required by Technical Specifications 7.8 and 7.9[(1)] shall specify the initial and, if necessary, the repeat reviews and approvals required for irradiations and experiments. Reviews shall involve a member of the Reactor Operations Group who holds a senior operator license and one or more of the following, depending on the nature and potential hazards:

a. MITR RPO
b. Reactor Engineering and Design Section
c. Electronics Section
d. MIT Reactor Safeguards Committee
e. Nuclear Regulatory Commission

Approvals shall be based on appropriate criteria required by the above Technical Specifications, and all reviews shall be documented in the reactor files. Where an experiment necessitates a change in any reactor equipment or any reactor standard, abnormal or emergency operating procedures, such changes shall be reviewed in accordance with the standard administrative procedure, which shall involve two or more of the above review groups.

Where the handling or storage of more than ___ g contained U-235 or ___ g of Pu is involved, the Criticality Officer shall participate in the review. The Criticality Officer shall also participate in the review of shipments containing more than __ g of U-235 or Pu or any combination thereof.

Reviews related to new equipment and procedures and to changes in these shall be distributed to all licensed personnel and to affected reactor users.

2.7.2 Materials Not Involving the Reactor

Where the use or storage of materials does not involve the reactor, control of the materials shall be accomplished by means of the authorization procedures described in Reference 3, and the establishment of written procedures for its use and storage shall be in accordance with the authorization application procedures. All authorizations undergo periodic review and renewal (two years) and the standard condition of approval assigns to the Project Supervisors the responsibility for initiating changes or amendments necessary for keeping authorizations up to date.

2.8 Audits

Audits of operating records shall be performed in accordance with written standard reactor administrative procedures. An annual independent audit shall be performed by one or more individuals who are not in the reactor operations chain of command. Such audits are concerned largely with reactor operation but also include MITR-RPP radiation surveys, environmental monitoring, radioactive effluent monitoring, and criticality safety, and will include such aspects for SNM used and/or stored at the reactor. During the annual physical inventory of all SNM under this license, an inspection shall be made to assure that labeling, posting, and criticality requirements are met. The quarterly administrative audit performed by the Director of Reactor Operations and/or Reactor Superintendent shall include the criticality safety of SNM in use and in storage at the reactor site. The Institute's radiation protection program is reviewed annually by the RPC.

Quarterly administrative update reports and the annual review of radiation protection activities are presented at the next meeting of the Campus Radiation Protection Committee or the Reactor Safeguards Committee, as appropriate. Any deficiencies shall be reported to the appropriate committee with the corrective action taken or recommended.

2.9 Investigation and Reporting of Occurrences

Reactor administrative procedures require the maintenance of a reactor console log; required entries therein include all reactor alarms and unusual conditions. Such entries shall be made with respect to materials held under this license when in use on the reactor. With respect to licensed materials at other locations, the MIT-RPP shall be notified by the dosimeter processor of external exposures that exceed the regulatory limits, any internal exposures and any accidental releases, in accordance with the requirements in Reference 3 and MRCP regulations in 105CMR120. In either case reports shall be made to the Nuclear Regulatory Commission as required by 10 CFR, Parts 20, 21, 30, 40, 50, 70, 71, and 73.

2.10 Records

Administrative procedures for the MITR and for the RPO specify that records generated by these two groups shall be maintained in the files indicated and for the times stated in the following Table I.2-1. Records of criticality reviews are retained in either Item 3 or Item 5 of the table. As for experiments and procedure and equipment changes, the records of criticality reviews shall be retained for at least five years and for such additional time as the subject reviewed is still in effect.

Accountability for receipt, inventory, and disposal of SNM and source material is maintained through Accountability Officer and the Nuclear Materials Management and Safeguards System (NMMSS). Material control records are maintained under the supervision of the Accountability Officer pursuant to 10 CFR 70.51(c) and (d). Material status reports and transfer reports are completed and distributed pursuant to 10 CFR 70.53 and 70.54.

Chapter 3 RADIATION PROTECTION

3.1 Special Administrative Requirements

The operating procedures referred to in Section 2.7 shall be utilized by members of the Reactor staff and of the RPP staff to control the radiation exposures of radiation workers at the Institute and to maintain these exposures as low as is reasonably achievable (ALARA). Reviews of proposed activities made according to existing standard procedures shall include an evaluation of all potential sources of internal and external exposure. Consideration shall be given to the experience of individuals involved in the use of radioactive materials, the need for adequate training, procedures, and protective equipment, in order that all of these may be optimized for purposes of ALARA and for guarding against potential sources of unnecessary exposures. Such reviews shall be documented as described in Reference 3, Attachment 11, Appendix 7 (ALARA program) and in the reviews performed according to standard reactor administration procedures for materials used there.

3.2 Technical Requirements

3.2.1 Access Control

The reactor containment building and portions of the adjacent building NW12 shall constitute controlled areas as delineated on Figure I.2-2 by the "restricted area boundary". Institute labs/areas where radioactive materials are used or stored shall also be so designated when required by the RPC as a condition for approval of specific radioactive material authorizations, Reference 3, Attachment #7. All persons authorized to have access to any controlled area shall be registered with the RPP or RRPP as appropriate, shall be escorted by such a person, or shall otherwise be authorized by the MIT-RPP or the MITR-RPP.

All personnel, packages and equipment leaving the reactor building shall be monitored for residual activity and/or contamination. Protective clothing (laboratory coats, coveralls, booties, caps and/or gloves) is be used when there is a potential for contamination, as specified by the MITR-RPP. A change facility and shower is available within the reactor restricted area. Further control of access to the restricted area shall be as specified in the "Physical Security Plan for the MIT Research Reactor Facility".

Additional controlled areas shall be established as required by either the MIT-RPO or the MITR-RPO. All controlled areas where material under this license is possessed shall be posted with appropriate caution signs.

These posting and labeling requirements comply with 10 CFR 20.

3.2.2 Ventilation Requirements

The reactor building shall have a ventilation system capable of automatic isolation upon detection of excessive concentrations of radioactive gaseous or particulate materials in the building effluent as required by Reference 1, and equipped with high efficiency particulate air (HEPA) filters in the exhaust stream. A dilution factor of 3000 is authorized by Technical Specification 3.8-lb, except for particulates and iodines with half-lives greater than 8 days in each case.

Elsewhere, when performing operations that might produce airborne contamination, approved exhaust ventilation shall be employed, with appropriate filtration for effluent air when recommended by RPP, Reference 3, Section 10.3.7. When averaged over 24 hours, the concentration of airborne radioactive material entering the duct system of each laboratory must not exceed the limits for unrestricted areas unless otherwise authorized by RPP. Where an experiment could result in a release into the ventilation system that exceeds the average specified in 10CRF20, continuous air sampling of the effluent downstream shall be performed.

3.2.3 Instrumentation

Instrumentation for projects using radioactive materials, other than at the reactor, shall be as determined by the RPP and the RPC and specified in the authorization and Reference 3, Attachments 1 and Attachment 7. The Institute possesses approximately 250 radiation detection instruments of various types and sensitivity ranges. Radiation survey meters are calibrated on an annual frequency using NIST traceable sources.

For the reactor containment building the ventilation shall be equipped with a radiation monitor capable of automatically closing the building vents as required by Technical Specification 3.8-2a of the reactor license(1). Other fixed instrumentation in the reactor building is required by standard operating procedures to include one gaseous monitor and one particulate monitor sampling the exhaust air entering a holdup plenum prior to the exhaust isolation damper and similar monitors downstream of the damper and exhaust HEPA filters. Normally two of each type are in operation. Standard operating procedures also specify a monitor in the building exhaust stack. All of the foregoing will detect excessive releases of airborne activity from licensed material within the reactor containment and will initiate an alarm if the activity exceeds a specified trip point. Fixed filter air samplers with continuous readouts

normally are operating on the reactor top, in the control room, and on the main reactor floor; in addition, the filters are analyzed weekly by the Reactor RPO. Area monitors continuously check radiation levels at various points in the building, at least one of which shall be functioning whenever the reactor is in operation, as required by Technical Specification 3.8-5. A number of survey meters (Geiger Mueller and/or ion chambers) are available in the building, and they shall be employed as specified in standard operating procedures, in special procedures or as required by the MITR-RPO.

A criticality monitor shall be located at the vault (Figure 1.2-2) where material under this license is stored whenever the total amount of fissionable material there exceeds the quantities specified in 10 CFR 70.24(a). The trip point for the high alarm is set according to 10 CFR 70.24(a)(2), and there is also a low level alarm to provide instrument failure protection. Material held under this license may be combined with reactor fuel in a storage location in the basement of the reactor building, in which case a criticality monitor shall be installed there whenever the total quantity of fissionable material exceeds 10 CFR 70.24(a). In the event of monitor failure, repairs shall be made as soon as practicable, and no activities that could increase reactivity shall be permitted until the monitor is properly functioning again. Calibrations and alarm checks for the criticality monitors are performed in accordance with written procedures.

Plutonium sources listed in Table 1.1-1 shall be leak tested by the methods and at the frequencies specified below:

a) Sealed Sources - Wipe test at intervals not to exceed six months, except when in storage.

b) Plated Sources - Alpha survey or wipe test of container or mount at least once very three months.

Details of the leak test methods are contained in Appendices 1 and 2 respectively.

3.2.4 <u>Performance Requirements</u>

Because of the many types of radioactive materials in use in a research and development environment and the many differing conditions under which they are employed, it is not meaningful to attempt to establish performance requirements for each aspect of each application. The overall performance requirements for internal and external exposures shall be those promulgated by the RPC in Reference 3, Attachment #11 or through procedures and safety reviews as performed at the reactor

facility.

The program for monitoring internal and external exposures is described in Reference 3, Attachment #8 and #9 and reactor license and implementing procedures The nature and extent of the program (e.g., types and capabilities of monitors), will depend upon each situation

Users of dispersible material which may result in internal deposition shall participate in the bioassay program described in Reference 3, Attachment #9 or within reactor and RRPP procedures as appropriate.

The need for protective clothing is determined during the review of the proposed use of SNM and is referenced in the authorization approval process. Proper personnel protective clothing is worn when working with SNM and in addition, general requirements for the use of protective clothing, personal monitoring after work, and notification to RPP regarding residual contamination are contained in Reference 3 or as that described for the reactor facility detailed above.

The surface contamination surveillance program, including frequency of surveys, tolerance levels, and action levels, shall be conducted in accordance with Reference 3, Attachments #12 and #13. Contamination in excess of the specified action levels shall result in immediate steps to decontaminate the area.

The licensee shall prepare and follow a descriptive operating procedure in conducting all work involving the licensed material. The procedure and its changes shall be approved by the Radiation Protection Committee or RSC as appropriate

3.2.5 Inspections

Inspections of radiation safety inspections are conducted in accordance with the conditions specified in Radioactive Materials License 60-0094 and the Reactor License R-37.

3.2.6 Release of Equipment

Release of equipment, facilities, or packages to the unrestricted area or to uncontrolled areas onsite shall be in accordance with the attached "Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material," dated April 1993.

Chapter 4 NUCLEAR CRITICALITY SAFETY

4.1 Special Administration Requirements

4.1.1 Policy

It shall be Institute policy to assure criticality safety in the use and storage of special nuclear materials through strict adherence to the special administrative requirements and technical requirements specified in this and the following section.

Although small (gram and fractional gram) quantities of SNM are used in a few authorized laboratories at the Institute, quantities of SNM exceeding the limits given in 10 CFR 70.24(a) shall not be possessed in any one of the two locations authorized in Section 1.5 except within the restricted area shown in Figure I.2-2. Because SNM in the form of reactor fuel under Facility Operating License No. R-37 is also possessed in the restricted area, the handling and storage of reactor fuel shall be taken into account in any criticality reviews performed for SNM held under this License No. SNM-986.

MIT's approach to criticality safety shall be based on the double contingency policy, which means that storage and experiments shall incorporate sufficient margins of safety so that two unlikely, independent, and concurrent changes in conditions are required before a criticality accident is possible, for instance, double batching plus flooding with water.

Implementation of the above policy is described in Section 4.2. Criticality safety for the quantities of low enriched rods listed in Items A and A-1 of Table I.1-1 is addressed in Subsections 4.2.1-4.2.5. The Item B possession limit of 350 g of U-235 for all other enriched uranium is based on the double contingency safe mass limit given in TID-7016, Rev. 1[(4)] and TID-7028[(5)] and is consistent with ANSI/ANS-8.1-1988, (endorsed by USNRC Regulatory Guide 3.71). The quantity and forms of Pu to be possessed for purposes other than storage pending disposition do not represent a criticality hazard.

4.1.2 Organizational Responsibility

Responsibility for criticality safety shall reside in the Criticality Officer shown on the organization chart of Figure I.2-1. As stated in Section 2.2, he shall be responsible for providing advisory and technical services with regard to the use, storage and shipping of SNM where criticality

considerations are involved. Criticality considerations are involved for all use and storage of SNM within the restricted area boundary at the Reactor site and for SNM to be shipped when the quantity exceeds 15 grams.

The MIT Accountability Officer shall be responsible for assuring that quantities of SNM in excess of 10 CFR 70.24(a) limits are not possessed in any one of the two locations authorized in Section 1.5, except within the reactor restricted area. Hence, there should be no criticality considerations involved in connection with such materials.

In the event of a disagreement between the Criticality Officer and a Research Project Supervisor, the latter shall follow the more conservative course. The matter shall be referred to the appropriate Department Laboratory or Center Head and to the Chairman of the Reactor Safeguards Committee for a resolution and or the Radiation Protection Committee as appropriate.

The Criticality Officer shall have the educational and experience qualifications required of the MITR Superintendent, as described in Technical Specification 7.3[1]. Minimum qualifications of the Director of Reactor Operations are also given in that document. The Accountability Officer shall have an associate's degree or higher in a technical field or shall have acquired equivalent knowledge through experience. The positions of Criticality Officer, Accountability Officer and Director of Reactor Operations may be filled by the same or by different individuals.

4.1.3 Review Process

The criticality review process shall apply to SNM within the restricted area boundary at the reactor site and to the shipping of SNM in quantities exceeding 15 grams of U-235 or Pu or any combination thereof. It shall be conducted in accordance with Section 2.7.1. Use and storage of SNM outside the restricted area is limited by the administrative policy of Section 4.1.1 to subcritical quantities and need not be subject to a separate review for criticality safety.

The purpose of the criticality review shall be to assure that:

(a) the use and storage of SNM within the restricted area boundary complies with the requirements of License No. SNM-986.

(b) the shipping of SNM complies with all NRC and DOT requirements in the Code of Federal Regulations, Titles 10 and 49.

Strict adherence to limitations on quantities of SNM and care in

maintaining geometry, neutron absorbers, and/or freedom from neutron moderations, where applicable, will provide reasonable assurance against criticality accidents. For the use and storage of SNM within the restricted area boundary, the reviews are made in accordance with the standard administrative procedures covering reactor operation, as described in Section 2.7.1. The Director of Reactor Operations and the Reactor Superintendent serve as backup to assure that criticality safety is considered in the reviews. For the shipping of SNM, the reviews are a part of the routine determinations required by 10 CFR 71 and 49 CFR 173 prior to each shipment of radioactive materials package.

4.1.4 Posting and Labeling

All SNM and source material containers shall be marked or labeled. Information on the container should show the type of material, form, gross and net weights, and, for SNM, the enrichment and fissile isotope weight. In addition, for laboratories, storage vaults or other areas where SNM in quantities exceeding 350 grams is authorized, the location shall prominently display a sign showing the following information as a minimum:

a) Type of material permitted
b) Allowable quantity
c) Spacing of fissile units, if required
d) Restriction on presence of moderators, if required

4.2 Technical Requirements

4.2.1 Storage of Low-Enriched U and UO_2 Rods

The storage of the uranium and uranium oxide rods in Items A and A-1 of Table 1.1-1 shall be in steel trays having a cross section no greater than that of trays 6" wide by 5" high and of appropriate length, or in approved shipping containers. The trays are open at the top and ends and are supported in a horizontal position by means of a steel framework with a 12" spacing edge to edge. The type of storage shall be as follows, and rods of different enrichments shall not be stored in the same tray.

Table I. 4-1, Storage Limits

Material Type	Cladding* Diameter	Enrichment (w/o)	Storage Limits No. Rods	U(grams)	U-235(grams)
UO_2	1/2"	1.99	100		
UO_2	1/2"	1.099	100		
U	1/4"	1.143	200		
U	1/4"	1.016	200		
U	3/8"	0.947	150		

*U metal or UO_2 pellet diameter is less.

The trays shall be located in the vault designated NW12-103 Figure I.2-2.

4.2.2 Storage of Other Materials in the Vaults

Other authorized SNM, source and byproduct materials may be stored in separate trays, shipping or other contains in the vaults up to a limit of ___ grams U-235 per tray or container, provided that the above 12" spacing is maintained for such trays and containers. The PuBe neutron sources shall be stored in their shipping packages or comparable containers. The PuO_2-UO_2 rods shall not exceed the possession limit, ___ g, in one tray.

4.2.3 Storage of License SNM-986 Material with Reactor Fuel

The storage of SNM held under License No. SNM-986 with unirradiated reactor fuel held under Facility Operating License No. R-37 shall be so limited that a conservative calculation of the effective multiplication factor (Keff) does not give a value exceeding 0.85 when flooded and fully reflected by light water. This corresponds to ___ g U-235, __ w/o enriched, per lineal inch of storage position(2). U-233, Pu and low-enriched U-235 are not authorized (since limits for them were not calculated). Further information is provided in Section 15.3.2.

4.2.4 Thermal-to-Fast Flux Converters

(a) Any thermal-to-fast converter that uses the reactor as the thermal neutron source shall be protected from inadvertent criticality (1) by maintenance of the close packing of the fissile materials to limit the effective multiplication factor (Keff) to less than 0.7 in the event of flooding and (2) by precluding flooding; both of these unlikely and independent contingencies being required before criticality can occur

(b) Design and safety analysis of each thermal-to-fast converter shall be reviewed and approved by the Director of Reactor Operations and the Criticality Officer. If both positions are held by the same person, another individual who has experiences in criticality safety shall be appointed to conduct an independent review. Measurements of the effective multiplication factor (Keff) shall be documented in the facility's initial startup report.

4.2.5 Thermal Reactor Physics and Other Experiments

Experiments for thermal reactor physics or other purposes where a

moderator is assumed to be present shall be limited to 30 rods with enrichments not to exceed ____ w/o U-235. The maximum weights would be ____ g U and ____ g U-235.

4.2.6 Laboratory Solids and Solutions

The total quantity of SNM possessed by the Institute under this license in the form of solid and liquid laboratory specimens, Item B of Table 1.1- 1, shall consist only of uranium enriched in U-235 and shall not exceed ___ grams of contained U-235.

Neither solid nor liquid SNM waste shall be disposed of without the approval of the Accountability Officer and the Criticality Officer.

4.2.7 Shipping

As stated above in Section 4.1.3, criticality safety in the shipping of License No. SNM-986 materials shall be achieved by strict adherence to the regulations of the Department of Transportation (49 CFR 171-179) and of the Nuclear Regulatory Commission (10 CFR 71).

4.2.8 Security

The licensee shall maintain and fully implement all provisions of the NRC-approved Physical Security Plan, including changes made pursuant to the authority of 10 CFR 50.54(p) and 70.32(e). The approved Physical Security Plan is contained in Revision 41 to the "Safety Analysis Report for the MIT Research Reactor (MITR-II), Appendix 13.B," submitted by letter dated February 28, 2002.

Chapter 5 ENVIRONMENTAL PROTECTION

5.1 Effluent Control System

All solid SNM scrap shall be retained and all liquid SNM waste shall be converted to a solid for disposal in both cases by transfer to an authorized recipient. There shall be no routine measurable loss to liquid effluent streams (in accordance with Section 4.2.6).

For source material, solid scrap and liquid waste shall be disposed of as for SNM, except that liquid waste may be discharged to the sanitary sewer in small quantities as authorized by Reference 3, Attachment 11, Appendix 3.

There shall be no routine, measurable discharge of gaseous radioactive material held under this license (except radon) to gaseous effluent streams.

Where a potential exists for significant loss of SNM or source material to an effluent stream through accident, the MIT-RPO or MITR-RPO, as appropriate, shall determine the need for sampling and/or monitoring.

5.2 Environmental Monitoring

The ventilation exhaust from the reactor containment building shall be monitored for radioactivity levels as required by Section 3.2.3, Instrumentation. Monitoring of other exhausts within the reactor restricted area or elsewhere at MIT for radioactivity shall be as specified by the MITR-RPO or MIT-RPO respectively. The concentrations of non-radioactive pollutants in gaseous and liquid effluent streams from laboratories using materials under this license are below the threshold for reporting as specified by the Massachusetts Department of Public Health.

Chapter 6 SPECIAL PROCESS COMMITMENTS

No special processes other than those referred to in previous chapters are envisioned at this time.

Chapter 7 DECOMMISSIONING PLAN

Attached is the revised decommissioning plan for activities conducted under SNM-986. In addition, we maintained decommissioning funding plans/assurances for the R-37 license and the byproduct materials license 60-0094. All spaces utilized for the storage and use of special nuclear material are also covered by the other licenses. The decommissioning financial assurance documentation is attached at the end of chapter 7. Return of the facilities and grounds to unrestricted use will be subject principally to the decontamination and restoration required pursuant to termination of the latter two licenses.

Massachusetts Institute of Technology

Special Nuclear Material (SNM-986)

Decommissioning Funding Plan

February 11, 2016

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Introduction:

This decommissioning funding plan (DFP) was prepared using NUREG-1757 Volume 3 Rev 1 (2012) as a guidance document. The section designations correspond to the numbering system used in Appendix A.3 of the NUREG. As an additional resource Penn State's DFP dated December 18, 2013 (forwarded to us by the NRC) was used as a reference document.

The Massachusetts Institute of Technology has three licenses for the use and possession of radioactive materials. One broad scope license issued by the Commonwealth of Massachusetts Department of Public Health Radiation Control Program (MA 60-0094) and two from the Nuclear Regulatory Commission; R-37 which covers the 6 MW research reactor facility and SNM-986 which covers the special nuclear and source materials used in research and development and storage of DOE owned materials used in past R&D projects. The materials used under the research reactor license (R-37) is restricted to the reactor site (MIT building NW12) unless transferred to the MA broad scope license. Nearly all of the material licensed under SNM-986 is in storage at the MIT reactor. Use of any material is strictly controlled as described in the SNM license application.

The Massachusetts Institute of Technology (MIT) campus is primarily located along the Charles River in Cambridge Massachusetts. The majority of material licensed under SNM-986 is on the main MIT campus of which the MIT Research Reactor is part of. In addition to the main campus use sealed / contained sources are also used at the Bates Research and Engineering Center located in Middleton, MA, approximately 35 miles north of the Cambridge campus.

The likelihood of an actual decommissioning of only the SNM spaces is not applicable, because the termination of activities under License No. SNM-986 does not necessarily mean that the MIT facilities used for SNM-986 materials will no longer be used for activities involving radioactive materials. On the contrary, SNM-986 activities have been conducted either in the reactor which is covered by Facility Operating License No. R-37, or in facilities subject to use under MIT's Radioactive Materials License No. 60-0094. Return of the facilities and grounds to unrestricted use will be subject principally to the decontamination and restoration required pursuant to termination of the latter two licenses.

This DFP can be adjusted for inflation in the future every three years as is currently done for the DFP for the MIT research reactor. However, MIT will instead maintain a bond as in years past to cover the $1.125 million required by past regulations. The DFP estimate herein is approximately $340,000 and in ten years' time when SNM-986 is due for renewal this estimate will not exceed the $1.125 million already in use. This also is a significant buffer if any unforeseen situations were to arise such as spills or other contamination incidents involving licensed materials. MIT maintains records of information important to the decommissioning of MIT's licenses at the MIT Environmental Health and Safety Office and the MIT Nuclear Reactor Laboratory (NRL).

Other Decommissioning activities and Plans at MIT:

In 2011 MIT hired an outside contractor to decommission a building MIT had recently purchased. There were 54 rooms in the facility where radioactive materials were used and 5 of which were suspected of having potential radioactive material contamination. Two of the five rooms did ultimately require remediation. The total cost for planning, decommissioning, remediation, and final site survey was

$100,700. This cost adjusted for inflation from 2011 to 2015 and scaled to adjust for the SNM decommissioning and final site survey would be approximately $256,181 ($100,700 x 1.06 x 12/5). Inflation over 2011 to 2015 is 5.7% and 12 affected rooms in this DFP versus 5 rooms in the decommissioning. The estimate is conservative as there have been no contamination incidents to date involving the use of unsealed special nuclear material thus there is no residual contamination in any of the authorized spaces.

The table below (Table 1) indicates the current levels of funds available for decommissioning of licensed activities.

Table 1. Decommissioning Funds

License	Description	Current Funding	DFP Estimate
R-37	NRC Research Reactor	$35.7 million	$35.7 million
MA 60-0094	MA DPH Broad Scope	$1.125 million	By Regulation
SNM-986	NRC SNM and source	$1.125 million	$0.325 million

Basic Assumptions:

Several assumptions must be made to estimate the cost of decommissioning the facilities. These assumptions are listed below.

1. Compliance with 10 CFR 20.1402. The operations plans and the cost estimates are based upon meeting the release limit of 10 CFR 20.1402. This release limit requires that "residual radioactivity that is distinguishable from background radiation results in a TEDE to an average member of the critical group that does not exceed 25 mrem per year."
2. Although MIT has three licenses only MIT's SNM-986 license is considered in this DFP.
3. Decommissioning activities take place immediately after cessation of work with the material.
4. This DFP assumes an independent contractor will perform all work and that the Radiation Protection Staff is not involved in any part of the DFP.
5. Decommissioning estimates are based on current use of materials and locations plus a small increase in unsealed use space to cover any additional use in the near future. As required by NRC regulations, the DFP will be updated every three years to reflect the future status of inventories and locations.
6. Prior decommissioned use locations are not included.
7. MIT radiation laboratories are maintained in a clean condition and when contamination occurs it is cleaned to background radiation levels. MIT will continue this practice. This will ease any decommissioning efforts in the future.
8. Department of Energy (DOE) will remove all sources that are DOE owned from the site. As an example 98% of the enriched uranium and all of the natural uranium of material possessed by MIT under SNM-986 is owned by DOE.
9. No costs associated with the removal or dismantling of spaces beyond that required for decommissioning are included.
10. No license amendments are expected for decommissioning. All activities are within the normal scope of tasks currently performed on a regular basis in accordance with established written procedures.

11. Shipping containers and waste sites are available at the time of decommissioning. Contractors specifically licensed to ship large sources will perform the packaging and shipping of the material.
12. This DFP is based upon the assumption that the shipment of radioactive waste is possible.
13. Waste on hand equals one year's waste generation. This DFP assumes that one year's worth of normal operations waste is already on hand and waiting disposal at the start of decommissioning. Added to this amount will be the decommissioning waste so that the total amount of rad waste will be slightly larger than just from decommissioning only.

A.3.4 Facility Description Summary

NRC license numbers and types.

The Massachusetts Institute of Technology has three licenses for the use and possession of radioactive materials. One broad scope license from the Commonwealth of Massachusetts Department of Public Health Radiation Control Program (MA 60-0094) and two from the Nuclear Regulatory Commission; R-37 covers the 6 MW research reactor facility and SNM-986 for the special nuclear and source materials used in research and development and storage of DOE owned materials used in past R&D projects.

Only the decommissioning of SNM-986 is considered in this decommissioning funding plan.

Types and quantities of materials authorized under SNM-986.

A summary of the possession limit, locations of use, and types of material in use and in storage are outlined below. The maximum quantity of material that may be possessed and used is identified by isotope, enrichment, chemical and physical form, and mass in grams. Table 2 lists the maximum quantities of SNM that may be possessed by MIT under the license, SNM-986.

Table 2 - Possession Limits under SNM-986		
Material	Form	Quantity
A. Uranium enriched to ≤ wt% in the U-235 isotope	A. U02 pellets, clad in steel, aluminum, or zircaloy	
B. Uranium enriched to ≤ wt% in the U-235 isotope	B. Metal or U02, slugs, foils, pellets and other shapes, clad	
C. Uranium enriched to ≤ wt% in the U-235 isotope	C. Metal or U02, solid slugs, foils, pellets and other shapes, unclad	
D. Uranium enriched to ≤ wt% in the U-235 isotope	D. Metal, U02 & other compounds and alloys, solid slugs, foils, fission chambers, pellets, and other shapes clad and unclad, as laboratory solids and solutions	
E. Plutonium	E. Pu-Be neutron source and Pu-Al neutron filter	
F. Plutonium	F. Solid alpha source	
G. Plutonium	G. Solid, foils, pellets	
H. Natural uranium	H. Solid and solution	

I. Depleted uranium	I. Any	
J. Any byproduct material unseparated contained in any of the above	J. Unseparated	J. Quantities produced during irradiation
K. U-233	K. Solid	
L. Plutonium	L. Any	

Description of how licensed materials are used.

MIT uses SNM for research and training at various campus locations. The SNM and source material is only used at the following locations: the MIT Campus and MIT reactor, Cambridge MA and the Bates Research and Engineering Center, Middleton MA. Of the materials MIT is licensed to possess only a small fraction of that material is in actual use. Table 3 indicates the maximum expected use of materials and the locations.

Table 3 - Material Use and Locations			
Type of Use	Amount	Material Form	Location of use
fission chamber detectors	Max of _ grams per detector and total of 20 grams	Contained source	MIT Research Reactor and MIT Campus (PSFC* only)
contained foils of uranium and/or plutonium for irradiation in the MIT research reactor	Max of ___ g per foil and total of __ grams each element	Foil contained in a quartz vial	MIT Research Reactor
Pu-Be neutron source for detector calibration	___ grams	Sealed Source	MIT Research Reactor Bates MIT Campus
Natural uranium slugs (Al clad) for use in shielding / radiation detection experiments	___ kg	Clad uranium metal	MIT Research Reactor Bates
Depleted uranium for shielding /radiation detection experiments	_____ kg	Uranium metal	MIT Research Reactor

Uranium and plutonium in liquid form for the generation of calibration standards.	Max ____ug per isotope and total of 1 g	Liquid calibration standards	MIT Campus MIT Research Reactor
Pu-239 check sources	__ ug total	Electroplated standard	MIT Campus MIT Research Reactor Bates
Storage of SNM	Per License Limit	Various Forms	MIT Research Reactor

* PSFC – Plasma Science and Fusion Center is a research lab on the MIT main campus.

There is no significant waste expected to be produced as part of the use of SNM since all of the current use of materials is only sealed or contained sources. Any use of liquid sources, based on past use, would likely be very small quantities and not produce very much waste.

The DOE owns a significant amount of the material possessed by MIT and is obligated to take back the material. MIT is currently working with the DOE to return 99% of the material in our possession.

A more detailed description of activities for which the licensed material is used include the following:

1. Alpha sources: Electrodeposited plutonium alpha sources [Material F] are used on the MIT campus and at the Bates Linear Accelerator in the routine calibration of alpha detection devices used in health physics monitoring and radiation safety.
2. Use in fission chambers: Highly enriched U-235 [__ grams of Material D] is used for detection and measurement of neutrons generated in the MIT Reactor or Plasma Science and Fusion Center (PSFC) (an on-campus building). There are currently 12 fission chambers at the PSFC containing approximately 10 grams of HEU in total.
3. Use of neutrons generated by SNM: Plutonium-beryllium encapsulated neutron sources [Material E] are used for calibration of neutron monitoring devices and for research purposes at the MIT reactor facility. Calibrations of neutron monitoring devices are also performed at the PSFC and the Bates Research and Engineering Center. All calibrations are performed by the radiation protection programs or under its supervision.
4. Laboratory solids and solutions: Enriched, natural, and depleted uranium and plutonium are used in various forms, both solid and liquid [Materials D, H, I and L]. Depleted or enriched uranium and plutonium are used as "spikes" for calibrating analyses of geological specimens. Migration of uranium and plutonium in soil with regards to decontamination of contaminated sites has been studied. Identification and characterization of unknowns in soils requires the use of uranium and plutonium standards. Research and teaching uses involving small quantities (<__ grams) of SNM of low strategic significance are reviewed by the Radiation Protection Program health physics staff and reviewed and authorized by the MIT Radiation Protection Committee.

5. Neutron irradiations and flux measurements of the neutron flux spatial and/or energy distribution is periodically required in reactor irradiation facilities. Also, foil irradiation is done in these same facilities for the purpose of creating calibration sources with fission spectra. The only the materials listed for such purposes are foils of Items D, G and L.

Description of facility, including buildings, rooms, grounds, and description of where particular types of materials are used.

The SNM and Source material shall be used only at Institute facilities at the following locations: MIT Campus and MIT Reactor, Cambridge MA and Bates Research and Engineering Center, Middleton MA. Below is a description of each facility:

a. MIT Campus and MIT Reactor, Cambridge MA

Past use of unsealed material was in 6-017, N52-446 and 446A, NW13-204. Lab NW13-204 has been decommissioned and no longer uses radioactive materials. Labs _____ and ______ are still in use but have not used any material listed on the SNM-986 license in many years. These spaces are still checked on a routine basis for radioactive material contamination (both fixed and removable). None has been detected.

The MIT reactor facility is where almost all of the SNM is stored and historically used. Most of the material is in storage awaiting return to the DOE. The facility within the reactor where this material was used was decommissioned and repurposed in the mid-1990s. The exception to this is the use of sealed PuBe sources (1 Ci and 5 Ci) for detector calibration, Pu-239 calibration standards (0.15 uCi or less), contained uranium and/or plutonium foils for irradiation using the reactor facilities, and sealed fission chambers for the monitoring of neutron production. There is no use of any unsealed liquids or powders within the reactor facility.

The MIT Plasma Science and Fusion Center (PSFC) uses sealed fission chambers for the monitoring of neutron production in room NW21-154. Again there is no risk of contamination due to the routine use of this material.

b. Bates Research and Engineering Center, Middleton MA

Only sealed or contained materials have been and will be used at this facility (PuBe source and natural uranium rods). There is no significant risk of contamination.

Summary Table of the above information

Table 4 - Facility Where of Materials are Used				
Location	Unsealed material use	Sealed / contained material use	Storage only	Description of Space

	X			Formerly MIT central isotope use area. Recently cleaned out and renovated. No residual SNM or contamination. Future use of SNM is not likely.
	X			EHS Hot lab. No SNM has been used in these rooms but material is stored.
NW13-204	Decommissioned			Room is no longer a laboratory.
	Storage Only		X	This is the main storage area at the MIT reactor facility
		X	X	This is the location of the natural uranium pile. This is storage only. Detector calibrations are done in this area using PuBe sources.
	Storage Only		X	Storage area for PuBe sources.
Reactor Bldg.		X		Main reactor building. Use and storage of fission chambers.
		X		PSFC use and storage of fission chambers.
Bates (2 labs)		X	X	Use and storage of contained sources such as PuBe sealed source for detector calibration and natural uranium rods for accelerator experiments

Quantities of materials or waste accumulated before shipping or disposal.

Under the SNM license there is no waste accumulation annually. In past years when unsealed materials were in use there was approximately one 55 gallon drum of waste per year. Today a single drum of waste weighing 250 lbs at $7.00 per pound would cost $1750.00. There are used fission chambers that would require disposal once they were determined of no future use. Some of these chambers have become activated and would require a shielded cask for transport. These cost estimates are covered in the waste cost section below.

Volume of contaminated material, including that in the subsurface, containing residual radioactivity that will require remediation.

There is no current residual fixed contamination of special nuclear or source materials in any of MIT's facilities. This is due to the very clean nature of the past uses of unsealed materials and other materials are in a solid metal or contained/sealed form.

A.3.5 Number and Dimensions of Facility Components

Current facility dimensions and components related to SNM use

Table 5 - Number and Dimensions of Facility Components

Location	Fume Hood	Sink drain	Benches (sqft)	Shelving (sqft)	Floor (sqft)	Room Dimensions (feet)
6-017	5x2x5	1	40	20	960	48x20x8
N52-446 and 446A	5x2x5	1	80	60	180	9x20x10
NW12-103	0	0	0	0	400	20x20x10
NW12-133	0	1	72	0	1600	40x40x14
NW12-139C	0	0	0	0	360	12x30x14
Reactor Bldg.	0	0	0	0	4000	72 dia x30
NW21-154	0	0	0	0	2400	48x50x30
Bates warehouse II	0	0	0	0	220	11x20x10
Bates (OC19B-049)	0	0	0	0	412	16x12x10
Average unsealed use lab	1 hood	1 sink	60	40	600	---
Average contained use lab	0	0	12	0	1400	---

A.3.6 Planning and Preparation (Workdays)

For the purpose of decommissioning planning we will assume the two labs where unsealed material has been used in the past as representative of labs which may be used in the future. For the purpose of estimating costs we will assume that three additional labs will use of unsealed material in the future. As

for contained material and metals only the existing spaces will be considered since there is no anticipated future uses of these materials.

In summary there are assumed to be five labs each of 600 sqft, one hood, one sink, benches and shelving 60 and 40 sqft respectively. The average for the seven contained use and storage spaces is 1400 sqft of floor space and 12 sqft of bench.

Table 6 - Planning and Preparation (Workdays)					
Activity/days	Certified Health Physicist	Project Manager	Site Supervisor	HP Tech	Admin
Preparation of Documentation for Regulatory Agencies	2	2	1	0	2
Submittal of Decommissioning Plan	2	1	1	0	1
Development of Work Plans	2	2	5	0	0
Procurement of Special Equipment	1	1	1	0	0
Staff Training	1	1	1	1	0
Characterization of Radiological Condition of the Facility	0.5	0.5	4	8	0.2
Total (days)	8.5	7.5	13	9	3.2

A.3.7 Decontamination or Dismantling of Radioactive Facility Components (Workdays)

Table 7 includes an estimate of the number of workdays, by labor category, which will be required to complete decontamination and/or dismantling activities for each component in the five unsealed use labs.

Table 7 - Decontamination or Dismantling Components (Workdays)					
Component	Method	Certified Health Physicist	Project Manager	Site Supervisor	HP Tech
Fume Hood	Wipe down			1	2

Sink Drain	Wipe down			1	3
Benches	Wipe down			1	3
Floors	Wipe down			1	3
Walls	Wipe down			1	3
Ceiling tiles	test and dispose	0.25		1	1
Ductwork	test and dispose	0.25		1	2
Equipment	Wipe down			1	3
Other (supervision / review, analysis, etc.)		2	1		3
Total (days)	----	2.5	1	8	23

Table 8 includes an estimate of the number of workdays, by labor category, which will be required to complete decontamination and/or dismantling activities for each component in the contained use / storage labs.

Table 8 - Decontamination or Dismantling Components (Workdays)					
Component	Method	Certified Health Physicist	Project Manager	Site Supervisor	HP Tech
Benches	Wipe down			1	2
Floors	Wipe down			1	3
Walls	Wipe down			1	3
Ductwork	test and dispose	0.25	1	1	1
Equipment	Wipe down			1	2
Other (supervision / review, analysis, etc.)		2	1		5
Total (days)	----	2.25	2	5	16

A.3.8 Restoration of Contaminated Areas on Facility Grounds (Workdays)

There are no areas external to buildings where radioactive materials contamination has occurred or is anticipated from routine use for this DFP.

A.3.9 Final Radiation Survey (Workdays)

Estimated below in Table 9 is the number of workdays required to conduct a final radiation survey.

Table 9 - Final Radiation Survey (Workdays)					
Task	Certified Health Physicist	Project Manager	Site Supervisor	HP Tech	Admin
Final Site Survey	1	1	4	12	

Final Report	5	4	4	6	2
Total (days)	6	5	8	18	4

A.3.10 Site Stabilization and Long-Term Surveillance (Workdays)

There are no known or anticipated areas requiring site stabilization or long term surveillance.

A.3.11 Total Workdays by Labor Category

The total workdays estimated for each specific labor category from the applicable tables above are in Table 10.

Table 10 - Total Workdays by Labor Category (Workdays)					
Category	Certified Health Physicist	Project Manager	Site Supervisor	HP Tech	Admin
Planning and Preparation	8.5	7.5	13	9	3.2
Decontamination*	4.75	3	13	39	0
Restoration of Contaminated Areas	0	0	0	0	0
Final Radiation Survey	6	5	8	18	4
Site Stabilization	0	0	0	0	0
Total (days)	19.25	15.5	34	66	7.2

*This includes the preparation of radioactive wastes for shipping that are produced during decontamination.

A.3.12 Worker Unit Cost Schedule

Labor costs (including salary, fringe benefits, and corporate overhead) are estimated based on the sources listed after Table 11. All labor categories are included in the table. In some cases the closest match to the BLS title was used and is listed in the table.

Table 11 - Worker Unit Cost Schedule					
Activity/hours	Certified Health Physicist	Project Manager	Site Supervisor	HP Tech	Admin

Alternate Title	CHP	Construction Manager	HP	Nuclear Technician	Admin
Labor Rates* ($x1000/year)	$133	$108	$104	$84	$43
Benefits	22%	22%	22%	22%	22%
Overhead	30%	30%	30%	30%	30%
Year of Data	2015	2014	2014	2014	2014
Adjustment for inflation to 2015	NA	3%	NA	3%	3%
Total ($x1000/year)	$211	$176	$165	$137	$70
Total ($/day*)	$843.75	$705.71	$659.78	$548.88	$280.98
Per diem	$275.00	$275.00	$275.00	$275.00	$275.00
Total ($/day)	$1,118.75	$980.71	$934.78	$823.88	$555.98

* Assumes a 250 day work year.

Data in the above table is based on the following sources:

<u>Health Physics Society Salary Survey:</u>

Average CHP salary $132,600, average HP salary $103,704

http://hps.org/documents/2015_chp_salary_survey.pdf and
http://hps.org/documents/2015_salary_survey.pdf

<u>Bureau of Labor Statistics</u> for Massachusetts (May 2014, Boston-Cambridge-Quincy, MA-NH):

Project Manager -$107,990, Nuclear Engineers -$108,910, Nuclear Technicians -$84,320, and Administrative Assistants -$43,460

http://www.bls.gov/oes/current/oes_71650.htm

<u>GSA – General Services Administration:</u>

Government per diem for Boston / Cambridge $275

http://www.gsa.gov/portal/category/100120

A.3.13 Total Labor Costs by Major Decommissioning Task

Table 12 - Total Workdays by Labor Category (Workdays)						
Category	Certified Health Physicist	Project Manager	Site Supervisor	HP Tech	Admin	Sub Totals
Planning and Preparation	$9,509.38	$7,355.33	$12,152.14	$7,414.92	$1,779.14	$38,210.90
Decontamination	$5,314.06	$2,942.13	$12,152.14	$32,131.32	$0.00	$52,539.65

Restoration of Contaminated Areas	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Final Radiation Survey	$6,712.50	$4,903.55	$7,478.24	$14,829.84	$2,223.92	$36,148.05
Site Stabilization	$9,509.38	$7,355.33	$12,152.14	$7,414.92	$1,779.14	$0.00
Total (days)	$21,535.94	$15,201.01	$31,782.52	$54,376.08	$4,003.06	$126,898.60

A.3.14 Packaging, Shipping, and Disposal of Radioactive Wastes

Due to the nature of work at MIT with SNM-986 materials there is no significant waste produced on an annual basis. The past radioactive waste from the MIT research reactor and main campus can be used to estimate the possible SNM-986 waste for the DFP. Currently there are no liquid sources of SNM-986 materials so there would be no liquid radioactive wastes to be disposed of. Only DAW (Dry Active Waste) and metals will be considered. DAW typically consists of gloves, paper towels, and used lab supplies (plastic). An allowance for the removal of contaminated bulk materials, such as contaminated lab equipment or shelving, are considered in this plan as well.

(a) Packing Material Costs

The types and volumes of waste expected to be generated, along with the number and types of containers required for packaging the waste are listed. Multiply the number of containers required by the unit cost per container.

Table 13 Radioactive Wastes - Packing Material Costs

Waste Type	Volume	Number of Containers	Type of Container	Unit Cost of Container	Total Packaging Costs
DAW	1 cubic yard (0.75 m^3)	10	Box	$50	$500
Metals	55 gallon (0.2 m^3)	2	Drum	$85	$170
Assorted bulk materials	2.6 m^3 (4500 lbs max)	1	B25	$2250	$2250
Total					$2920

(b) Shipping Costs

Estimate the number of truckloads of waste to be shipped. Multiply shipping costs per mile (including truckload costs, surcharges, and overweight charges) by the total distance shipped.

The table below is based on the cost of recent waste shipments from MIT. A B25 container of assorted metals ($28980 at $6/pound, 4830 pounds), a high activity shipment of resin and mixed metal waste in twelve 55 gallon drums ($80,632 at $6.93 per pound for metals), and DAW materials in Drums and cubic yard boxes.

	Table 14 - Radioactive Wastes - Shipping Costs					
Waste Type	Number of Truckloads	Unit Cost ($/truckload)	Surcharges ($/mile)	Overweight Charges ($/mile)	Distance Shipped (miles)	Total Shipping Costs
DAW and Bulk Materials	1	$500	NA	NA	1000 miles	$500
Metals*	1	$19,290	NA	NA	1000 miles	$19,290
Metals* labor costs	1	---	---	---	---	$18,100
Total						$37,890

* based on a recent shipment of high activity materials from MIT. Labor cost for cask loading include HP and cask supervisor and crane operator ($16,600 +$1,500).

(c) Waste Disposal Costs

Below in Table 15 is an estimate of the weight of the waste to be disposed. The maximum weight typically shipped in a B25 box is 4000 lbs and the other two drums and ten cubic yard boxes would likely be another 1000 pounds based on past shipments.

Table 15 - Radioactive Wastes - Disposal Costs				
Waste Type	Disposal Mass (lbs)	Unit Cost ($/lbs)	Surcharges ($/lbs or $/container)	Total Disposal Costs
DAW and Bulk Materials	5000 lbs	$7.00	NA	$35,000
Metals	980 lbs	$7.00	NA	$6,860
Total				$41,860

A.3.15 Equipment/Supply Costs (Excluding Containers)

It is not anticipated that any additional equipment would be needed however a budget of $10,000 is added in in order to have the ability to purchase or rent equipment as needed.

Table 16 - Equipment/Supply Costs (Excluding Containers)			
Equipment / Supplies	Quantity	Unit Cost	Total Equipment / Supply Cost
Survey Supplies			$10,000.00
TOTAL	---	---	$10,000.00

A.3.16 Laboratory Costs

It is not anticipated that any analysis by an independent third party will be required.

Table 17 - Laboratory Costs			
Activity	Quantity	Unit Cost	Total Equipment / Supply Cost
Sample Analysis	0		$0.00
TOTAL	---	---	$0.00

A.3.17 Miscellaneous Costs

The NRC may bill for regulatory oversight efforts and is reflected in the table below.

Table 18 - Miscellaneous Costs	
Cost Item	Total Cost
NRC Oversight	$50,000.00
Total	$50,000.00

A.3.18 Total Decommissioning Costs

The total costs reported in the previous tables are reproduced into the table below and subtotaled. A contingency allowance of 25 percent of the subtotal is added to obtain the total decommissioning cost estimate. Also, the percentage of the subtotal for each task/component is also calculated.

Table 19 - Total Decommissioning Costs		
Task/Component	Cost	Percentage
Planning and Preparation (Table 12)	$38,211	14.5%
Decontamination and/or Dismantling of Radioactive Facility Components (Table 12)	$52,540	20%
Restoration of Contaminated Areas on Facility Grounds (Table 12)	$0.00	0%
Final Radiation Survey (Table 12)	$36,148	13.7%
Site Stabilization and Long-Term Surveillance (Table 12)	$0.00	0%
Packing Material Costs (Table 13)	$2,920	1%
Shipping Costs (Table 14)	$31,890	12%
Waste Disposal Costs (Table 15)	$41,860	16%

Equipment/Supply Costs (Table 16)	$10,000	3.8%
Laboratory Costs (Table 17)	$0.00	0%
Miscellaneous Costs (Table 18)	$50,000	19%
SUBTOTAL	$263,569	100%
25% Contingency	$65,892	---
TOTAL DECOMMISSIONING COST ESTIMATE	$329,461	---

February 24, 2016

United States Nuclear Regulatory Commission
Fuel Cycle Facilities Branch
Division of Fuel Cycle safety and Safeguards
Office of Nuclear Material Safety and Safeguards
Washington, D.C. 20555-0001

Attention: Tyrone D. Naquin, CHP
NMSS/FCSE/FMB

RE: Renewal of MIT SNM License-986

Attached please find the renewal application for the MIT SNM-986 license. There have been no changes in the use of licensed material during the past 10 years. The majority of the inventory remains in secured storage within the restricted area of our Nuclear Reactor Laboratory. An annual inventory of all licensed material is performed and reported to NMMSS. Most of the current licensed material inventory was transferred to MIT under DOE contracts and has been in storage for the past 20 years. We are working with our contracts department and their contacts at DOE to attempt to return or dispose of these stored materials. DOE has recently indicated there is potential to return the materials to Y-12.

Our current use of special nuclear material is limited. We use PuBe sources for detector calibrations, fission detectors for neutron detection, electro-deposited alpha sources for instrument calibration, solid/ liquid standards for instrument calibration, and foils in reactor experiments. Likewise, storage and use locations on the Cambridge campus are limited to the Nuclear Reactor Lab, the Plasma Science and Fusion Center, and several chemistry/analytical labs. At the Bates Linear Accelerator campus, we use a PuBe source for detector calibration and some natural uranium rods in accelerator experiments.

Our decommissioning funding plan has been updated to more accurately describe the future decommissioning/termination of license SNM-986. In addition, copies of our current financial assurance documents are enclosed in the application.

Please contact me if you have any questions or require additional information.

Thank you.

Mitchell S. Galanek
MIT Radiation Protection Officer
77 Massachusetts Avenue
Room N52-496
Cambridge, MA 02139
Tel: 617 258-9457
Mobile: 617 201-6590
Email: galanek@IT.edu

Chapter 8: EMERGENCY PLAN

The emergency plan covering License No. SNM-986 activities shall be the "Emergency Plan for the MIT Research Reactor", Appendix 13A of the "Safety Analysis Report for the MIT Research Reactor (MITR-II)", Report No. MITNE-115, as amended[(2)]. Since Section 4.1.1 of this application limits the amount of SNM that may be possessed outside the reactor restricted area to subcritical amounts, it is not useful to even postulate criticality accidents except at the reactor. The reactor emergency plan, together with existing written procedures for building evacuation, fuel vault criticality, medical emergency, fire, riot, hurricane and earthquake, is directly applicable to emergencies involving SNM-986 materials within the reactor restricted area.

For such materials elsewhere at MIT, the emergency procedures contained in Reference 3, Attachment 11, Appendix 4 shall apply.

PART II - SAFETY DEMONSTRATION

Chapter 9: OVERVIEW OF OPERATION

9.1 Corporate Information

9.1.1 Purpose and Organization

The Massachusetts Institute of Technology is an independent, coeducational, endowed university committed to the extension of knowledge through teaching and research. It is organized into five academic Schools - Architecture and Planning, Engineering, Humanities and Social Science, Management, and Science - and a number of interdisciplinary groups and activities. There are approximately 11,000 students, with approximately 40% studying for undergraduate degrees; about 1050 members of the faculty; and a total teaching staff of 1,800, including, in addition to the faculty, Lecturers, Instructors, and Teaching Assistants. Total employment at the Institute is 10,000, including research and library professional staff, members of the administrative staff and the many employees who, directly or indirectly, support the teaching and research goals of the institute.

The Institute is chartered under an Act of the General Court of the Commonwealth of Massachusetts.

The governing body of the Institute is a board of trustees known as the Corporation, over which the Chairman presides. Its members include 90 distinguished leaders in science, engineering, industry, education, and public service, and (ex officio) the President, Treasurer, and Secretary of the Corporation. Three representatives of the Commonwealth of Massachusetts and the President of the M.I.T. Alumni Association also serve as ex officio members of the Corporation. Between quarterly meetings the Corporation functions through its officers and Executive Committee.

The Corporation appoints Visiting Committees for each department and for certain of the other major activities of the Institute. These Committees, whose members are leaders in their respective professions, make recommendations to the Corporation concerning departmental activities and in turn provide counsel to the departments.

The Institute's chief executive officer is the President. In addition, senior administrative officers of the Institute include the Provost, the Associate Provost, and several Vice Presidents. The academic program is

directed by the President, the Provost, the Associate Provost, and five Deans, each responsible for the undergraduate and graduate programs in one of the five academic schools.

The principal officers of MIT currently are:

a) ______, President
b) _______, Provost
c) __________, Executive Vice President and Treasurer
d) _________, Secretary

Addresses for the above are the same as for the principal office (Section 1.2). All are United States citizens. There is no control or ownership exercised over the Institute by any alien, foreign corporation or foreign government.

Much of the teaching and research that depends on materials held under this license falls under the jurisdiction of the above academic program. Much of it, however, is under the jurisdiction of interdisciplinary laboratories and centers that have been organized to facilitate research fields which cross the lines of traditional disciplines. The Nuclear Reactor Laboratory is the principle such laboratory that uses materials held under this license. It provides the focus for a wide range of research programs that involve the use of nuclear radiations in such areas as trace element analysis, neutron and nuclear physics, neutron scattering, radiation effects, nuclear medicine and others.

The Bates Linear Accelerator, which is administered by the interdisciplinary Laboratory for Nuclear Science, supports an active program in the study of the nucleus and its components through high-precision neutron scattering experiments using electron beams ranging in energy up to more than 900 MeV.

9.1.2 Location

The main campus, which includes the Nuclear Reactor Laboratory and most of the other laboratories where material under this license is used, is located on about 125 acres along the Charles River in Cambridge (Middlesex County) less than one-half mile across the river from Boston. Lincoln Laboratory is 15 miles northwest of Boston in Lexington, Massachusetts (also Middlesex County), and the Bates Linear Accelerator is 20 miles north of Boston in Middleton, Massachusetts (Essex County). Both are just outside the Greater Boston suburban area.

9.2 Financial Qualification

Copies of MIT's financial statement (Schedules A-E, with notes and the auditor's report), for the year ending June 30, 2015, are attached in the financial assurance for decommissioning section.

9.3 Summary of Operating Objective

The utilization of materials possessed under this license is to assist in the implementation of the Institute's primary objective: The advancement of knowledge through education and research, in this case nuclear technology and its applications.

9.4 Site Description

The site of principal interest is the restricted area (Figure I.2-2) of the Nuclear Reactor Laboratory, since the vast majority of the material is used at that location. Smaller quantities are used nearby at other locations in the Cambridge Campus, while very small amounts (sometimes none) are used at Lincoln Laboratory and the Bates Accelerator.

A description of the reactor site (which includes the restricted area) and its topography, demography, meteorology, hydrography and seismology is contained in SAR Chapter 2. While it was written for the Cambridge area, much is applicable to the Middleton and Lexington locations.

9.5 Location of Buildings

A map is attached as Figure II.9-1 showing the major features and location of the Cambridge Campus. The locations of the Nuclear Reactor Laboratory, MIT Radiation Protection Office, and Central Radioisotope Facility are indicated on the map. The MITR-RPO is located in the Nuclear Reactor Laboratory, Building NW12. Figure I.2-2 shows in more detail the location of the Nuclear Reactor Laboratory and also the reactor restricted are boundary.

9.6 Maps

A map of eastern Massachusetts is attached in reference 6.

9.7 Changes in Procedures, Facilities and Equipment

The operating procedures described in Section 2.7 assure that safety reviews are conducted under the supervision of either the Reactor Staff or the Radiation Protection Officer, as appropriate, and documented in sufficient detail to permit independent review with maintenance of the

records in accordance with Section 2.10. At the reactor, the Director of Reactor Operations has responsibility for assuring that the review is conducted at the proper administrative levels, as provided in the reactor Technical Specifications, while the MIT Radiation Protection Officer has a similar responsibility for materials not within the reactor site, as described in Sections 1 and 2, Reference 3, Attachment 1 and Attachment 2. The level of management authorized to review and approve changes depends upon the extent of the changes. Ultimate responsibility rests with either the Reactor Safeguards Committee or the Radiation Protection Committee, but each may delegate authority to the Reactor Staff or to the RPO staff, as appropriate.

Chapter 10 FACILITY DESCRIPTION

The MITR-II Safety Analysis Report (SAR), Reference 2, contains detailed descriptions of the reactor facility features listed in the Draft Regulatory Guide (Task FP 716-4). References to applicable sections of the SAR are given in the following table II.10-1.

Table II.10-1, SAR References

Draft Regulatory Guide Paragraph	Feature	SAR Section
10.1	Plant Layout	2.2, 5.1, 5.2
10.2	Utilities, Emergency Power	8, 9.1, 9.9
10.3	Ventilation	5.2
10.4	Waste Handling	12.1
10.5	Chemical Systems	see below
10.6	Fire Protection	15.7

For material under this license outside the reactor restricted area, laboratory facilities typical of those at teaching and research institutions are employed for use and storage. For each proposed use, the adequacy of the facilities are evaluated during the authorization process in Reference 3, Attachment 11. For operations involving relatively large amounts of activity the RPO operates the Institute's Central Radioisotope Laboratory and Storage Facility (Room 6-017). Waste disposal is described in Reference 3, Attachment 11, Appendix 3.

There are no large-scale chemical systems used in connection with the licensed material. With the exception of the laboratory activities described in paragraph 1.7.12, which uses Items B, H, and L, all utilization is in solid form.

Fire protection at MIT is supervised by the Committee on Safety, whose policies are implemented under the direction of the EHS Safety Office. This office is headed by a Safety Officer, qualified by education and experience; he or another representative of the Safety Office serves as a member of the RSC. The Safety Officer is assisted by a staff of about six certified safety professionals; they provide advice and guidance on fire protection, including NEPA standards, insurance and building code requirements, and use of qualified vendors for the design, installation and maintenance of all fire protection equipment. The Institute in general is protected by property damage and comprehensive liability insurance policies and, at the reactor site, by nuclear property and liability insurance policies, and is subject to periodic inspections by the several companies providing the coverage.

Chapter 11 ORGANIZATION AND PERSONNEL

Chapter 2 provides information regarding pertinent parts of the Institute organization, responsibilities, and authority and states the personnel education and experience requirements for key individuals. One of these, the Criticality Officer, has the responsibility for the criticality safety of SNM possessed under this license by providing advisory and technical services with regard to the use, storage and shipping of such SNM where criticality considerations are involved. Specifically, he is responsible for:

(1) preparing criticality safety analyses, reports and applications,
(2) administering the criticality safety aspects of this license,
(3) assuring proper reviews of handling and storage of SNM,
(4) development, review and implementation of written procedures,
(5) assuring adequate training of personnel,
(6) maintaining a file of necessary regulations, guides, standards and safe handling criteria,
(7) assuring compliance with the above and with internal procedures and license requirements through reviews and audits,
(8) investigating and correcting items of non-compliance.

The following individuals have significant roles in the safe storage and use of special nuclear materials:

Compliance Officer and Criticality Officer
Accountability Officer
Interim Director of Operations
Interim Superintendent of Reactor Operations
Reactor Radiation Protection Officer
Institute Radiation Protection Officer

The annual independent audit specified in Section 2.8 has been performed by an independent consultant and the audit report submitted to the RSC.

As indicated in Reference 3, the MIT Radiation Protection Officer is supported by a technical staff of about 9 health physicists (4 CHPs) and 10 health physics technicians. The above reactor personnel are supported by about 10 licensed reactor operators and senior operators, 3 health physics technicians, and at least 15 others in mechanical and electronics maintenance, the reactor machine shop and research projects in the Nuclear Reactor Laboratory who are experienced in the handling of radioactive materials and who can be called upon for assistance in emergency situations. MIT faculty, particularly in the Department of Nuclear Engineering, local consultants, and staffs of area companies in the nuclear technology field may be called upon for expert advice on specific problems as required to augment the staffs of the reactor, RPO and EHS.

Chapter 12 RADIATION PROTECTION PROCEDURES AND EQUIPMENT

12.1 Procedures

In terms of total mass of SNM and source materials and total activities held under this license, the largest quantities are located within the reactor restricted area (securely stored in the BTF vault) and are covered by reactor radiation protection procedures and equipment. These are described in detail in SAR[(2)] Sections:

12.3.1 Reactor Radiation Protection Office
12.3.2 Radiation Protection Program
12.3.4 Radiation Protection Equipment

Similar materials possessed at other parts of MIT are covered by the required procedures in Reference 3.

12.2 Postings and Labeling

MIT's required procedures contained in Reference 3 provide for the posting and labeling of radioactive material laboratories and containers. They are applicable to the posting and labeling of materials held under this license, as stated in Section 3.2.1. Criticality safety limits are posted as stated in Section 4.1.4.

12.3 Personnel Monitoring

All personnel at the reactor are required to wear Luxel monitoring badges and electronic dosimeters, as described in SAR paragraph 11.1.5.1; personnel monitoring devices are required for other personnel as described in Reference 3, Attachment 8. The Luxel dosimeters are capable of measuring potential neutron exposures. For fast neutron doses in the event of a criticality accident, threshold dosimeters are located at several points inside the reactor building and at the two fuel storage vaults outside the containment.

12.4 Surveys

Health physics technicians at both the MIT RPO and the Reactor RPO make routine periodic radiation surveys, wipe tests, and air samplings, the results of which are recorded for review and action, if needed, by staff members of those offices. The frequency of the surveys depends upon the nature of the activity and whether any unusual operations or maintenance may be in progress.

12.5 Reports and Records

All persons working at the reactor and all others at MIT who wish to use radioactive materials are required to register with either the reactor RPO or the MIT RPO, as appropriate. A record of the registration and the individual's radiation exposure history are maintained on a record of the type illustrated by Reference 3, Attachment 8.

A list of radiation protection records generated at the MITR and the MIT RPO was provided in section 2.10, along with retention items for the records.

Records related to the receipt, transfer, shipment, consumption and loss of SNM, together with records of physical and book inventories of SNM for the entire Institute are maintained by the Accountability Officer of the Nuclear Reactor Laboratory Headquarters Office.

12.6 Instruments

Instruments for area monitoring at the reactor are described in SAR[(2)] Section 12.3.2.4, and radiation protection equipment is described in Section 12.3.4. Instruments possessed by the MIT RPO and calibration procedures are described on Reference 3, Attachment 6.

12.7 Protective Clothing

Protective clothing (laboratory coats and foot covering plus overalls, booties, gloves, head covers, etc., as needed) are routinely used at the reactor in contaminated or potentially contaminated areas, such as the reactor top. For special maintenance or accident conditions other protective equipment includes respirators, self-contained air breathing units, and full face masks (positive pressure). Change rooms are available at the reactor for showers and decontamination facilities are available at the reactor and the MIT Medical Department Infirmary.

12.8 Administrative Control Levels

External occupational exposures are reviewed at least monthly, based on the dosimetry results. Transfer of an individual to a job with lower exposure potential is initiated if his or her dose exceeds the limits specified in Reference 3, Attachment 11, Appendix 1.

The procedures for control of internal exposures and associated administrative action levels are described in Reference 3, Attachment 8 and Attachment 9.

Action levels related to the release of radioactivity in effluents at the reactor

are specified in written abnormal and emergency procedures. However, for the diverse activities conducted in teaching and research laboratories in other parts of MIT, it is not feasible to establish action levels in each. Instead, the RPO is notified in the event of the known or suspected circumstances listed in Reference 3, Attachment 11, so that appropriate administrative action may be taken by staff members of that office, as required.

12.9 Respiratory Protection

A respiratory protection program is not required at any of the Institute facilities in order to meet the maximum permissible dose values given in Appendix 2 of Attachment 1, Reference 3, because all routine work and maintenance activities are planned so that gaseous concentrations in the work area will not exceed the activities specified in 10 CFR 20, Appendix B, Table 1, Column 1. Respirators may be specified, however, by staff members of the MIT RPO or Reactor RPO to maintain exposures ALARA.

Chapter 13: OCCUPATIONAL RADIATION EXPOSURES

13.1 Occupational Exposure Analysis

Individuals who work with the radioactive materials possessed under License No. SNM-986 normally incur very low exposures for several reasons, including some or all of the following:

a) The exposure is usually intermittent only.
b) The work frequently involves very small quantities.
c) Sources are shielded as necessary.
d) The work is planned to maintain doses as low as reasonably achievable in all cases.

Since most individuals who use these materials do so within the reactor restricted area and usually within the reactor containment, their radiation badges also record exposures attributable to the reactor.

For most others using these materials away from the reactor, the anticipated exposures are so low that personnel monitoring devices are not required, except at the Bates Accelerator where, as at the reactor, doses from materials under this license are negligible compared to the individual's total dose. It is not feasible to separate the exposures; however, they are minor, since they are only a small fraction of the above.

13.2 Measures Taken to Implement ALARA

The administrative procedures of Section 3.1, as further described in Paragraphs 2.7.1 and 2.72, are intended to maintain occupational radiation exposures as low as reasonably achievable, and the extent to which this is being accomplished is indicated by the fact that three-quarters of those referenced in section 13-1 above incurred exposures of less than 0.1 rem.

Individuals are instructed in the principles of ALARA when registered as radiation workers and when specific projects involving radiation are reviewed. Those at the reactor carry direct reading pocket dosimeters as well as film badges, so that an individual can monitor his exposure on any particular job. This last practice applies principally to reactor maintenance work rather than to use of materials under this license where potential exposures are much lower.

13.3 Bioassay Program

The Institute's bioassay program described in Reference 3, Attachment 9.

13.4 Air Sampling Program

At the reactor the effluent air stream is monitored by gaseous and particulate radiation detectors, as described in Paragraph 3.2.3. In addition, air samplers with continuous readouts are normally operating on the reactor top, in the control room, and on the main reactor floor; the filters from these samplers are analyzed weekly by the Reactor RPO. Portable air samplers are employed for experiment changes, maintenance or other activities, either at the reactor or other locations, where there is a potential for airborne activity. Filters are counted for alpha and gross beta-gamma activity, which usually indicate concentrations that are orders of magnitude less than MPC. Any detectable increase in levels of activity are cause for investigation; when observed, they are usually attributable to reactor sources.

13.5 Surface Contamination

Surface contamination surveys are made by means of filter paper wipes routinely (daily, weekly or monthly), the frequency depending upon the potential for contamination. Survey surveys are also made routinely during or after experiment changes, maintenance, or other activities where there is a potential for surface contamination. For various areas in the reactor and for other area where material under this license is used, guidelines have been established to initiate cleanup or isolation. Please refer also to Section 3.2.4.

A hand-and-foot monitor is located at the main personnel lock for the reactor containment. All personnel leaving the containment at this point or having reason to suspect possible contamination from other sources on person, tools, equipment, etc., are required to use the monitor. Decontamination facilities are located in the same area for use if needed, and the Reactor RPO and laboratory are nearby, as indicated on Figure I.2-2.

13.6 Shipping and Receiving

Incoming shipments of radioactive material are received either at the reactor site (Building NW12) or at an MIT Shipping and Receiving Room. Packages are inspected by a member of the Reactor or MIT RPO, as appropriate, and monitored for external radiation and surface contamination, in accordance with 10 CFR 20.205.

Shipments of radioactive material are packaged at the reactor site, the RPO Central Radioisotope Facility or another location approved by the MIT RPO. Packaging and shipping arrangements are reviewed and approved

by the Director of Reactor Operations and the Reactor Radiation Protection Officer for materials shipped from the reactor site and by an MIT RPO member for material shipped from other locations. Shipments must meet the requirements of the Department of Transportation (49 CFR 171-179) and of the Nuclear Regulatory Commission (10 CFR 71).

Chapter 14: ENVIRONMENTAL SAFETY--RADIOLOGICAL AND NONRADIOLOGICAL

The Institute has had an extensive radiological environmental monitoring program since before the start of reactor operation in 1958. This includes measurements of radioactivity levels in reactor discharges to the air and to the sanitary sewer and measurements at a series of monitors on the MIT Campus surrounding the reactor site. The latter are recording monitors that use end-window Geiger-Mueller counters as detectors, and hence are very sensitive to increases of even a few percent above the continuously recorded background. Ever since these went into operation several years ago they have recorded an average increase of only 2% in the annual background. Essentially all of the increase is attributable to reactor operation, and none of it can be attributable to activities conducted with the special nuclear materials held under this license.

Small quantities of chemicals of the types normally found in teaching and research laboratories are the only nonradioactive pollutants that could potentially be released liquid effluents from laboratories using materials under this license, and these have a negligible impact on the environment, as indicated in Section 5.2. Since 99% of the current use of special nuclear material source is in solid form, no impact on the environment is anticipated.

Chapter 15 NUCLEAR CRITICALITY SAFETY

15.1 Administrative and Technical Procedures

It was stated in Section 4.1.1 that, as a matter of MIT policy, quantities of SNM exceeding the limits given in 10 CFR 70.24(a) shall not be possessed in any of the locations authorized in Section 1.5 except within the restricted area shown on Figure I.2-2. Criticality safety is therefore a matter of practical concern only within the restricted area. Chapter 2 described the organization and the administrative controls existing at the Institute to deal with the health and safety aspects of radioactive, including fissile, materials. Chapter 11 provided additional information.

It should be emphasized that experience in the area of criticality safety has been accumulating at the MIT Reactor over a period of about 35 years, and such experience is directly applicable to questions of criticality safety arising in connection with the use and storage of materials held under this license. In addition, the Department of Nuclear Engineering, established in 1958 has in recent years totaled more than 20 faculty members, who are available for consultation in a wide variety of fields (nuclear engineering, reactor physics, fuel management, radiation effects, structural mechanics, health physics, etc.) and some of whom serve on the Reactor Safeguards Committee.

Much of the experience that has accumulated at the reactor is reflected in the written procedures referred to in Chapter 2 and elsewhere. These encompass the administrative procedures, including reviews of irradiations and experiments, changes in procedures and equipment, standard operating procedures, abnormal and emergency procedures, surveillance testing and calibrations, preventive maintenance, etc. The experience and review procedures related to the reactor are directly applicable to safety in the use and storage of SNM in the reactor restricted area, including criticality safety.

Other necessary and useful resources include files of USNRC Regulatory Guides and pertinent American National Standards, a reading room maintained by the Department of Nuclear Engineering, and the central engineering and science libraries of MIT.

15.2 Approach to Design

Most utilization and storage of SNM, as is seen by a review of Table I.1-1, is concerned with small items which have little or no criticality safety significance individually and, for most items, in the aggregate. Those having criticality safety significance and the methods of assuring safety were enumerated in Section 4.2. The chances for accumulating dangerous

quantities of fissible materials in inaccessible locations, such as by misplacing fission foils or other fissile material, are almost nonexistent, because the quantities of SNM available for such an accumulation are small compared to a critical mass. Where significant quantities exist, such as for the rods in Item A, the 4 ft lengths do not make inadvertent accumulations a credible scenario.

15.3 Basic Assumptions

For all SNM except that in Items A and A-1, the basic assumption is that the quantities are two small to constitute critical masses, in general much less than 0.45 of the minimum critical mass based on spherical geometry. Nevertheless, all use is evaluated for criticality considerations, as specified in Section 4.1.3, to reduce the possibility of aggregations occurring.

In all criticality analyses for Item A and A-1 materials, fast criticality is not possible because of the low enrichment (1.99 w/o or less), and so it is not necessary to consider interaction between arrays in the absence of moderators.

15.3.1 Storage and Low-Enriched U and UO_2 Rods

The storage limitations for these materials was given in Section 4.2.1. It is assumed for the storage array that water flooding is possible, although it is difficult to envisage its occurrence due to the fact that the storage array is in a vault without a water supply, the floor level of the vault is slightly above grade, and any flooding of the local area would drain at once into the Charles River and then into the ocean. If flooding occurs, water cannot fill the trays without filling the spaces between (due to the open ends of the trays), and so the trays will be isolated from each other by virtue of the 12" of water between them.

a. 1/2 inch diameter rods

The most reactive condition which has to be considered for these rods is an isolated tray of the 1.99% enrichment rods which is immersed in water. The ___% rods will be less reactive, as will a dry tray. Some rods have a 0.1" diam. wire helically wrapped around the rod. If the rods without wires are loaded into a try, the water to UO_2 ration will be close to 0.4. If the rods with wires are loaded into a rectangular array, with the wires touching so the center to center spacing is 0.7 in., the water to UO_2 ratio is 2.0 (V_{H2O}/V_U = 4.5). The wider spaced assembly is more reactive. The worst possible case is __% enrichment, optimum water to UO ratio (actually ≈3 instead of 2), infinite water reflector, and zero absorption assumed for the cladding and wires. It is this case which is considered in the criticality analysis described in the following

paragraph.

Calculations have been performed by Westinghouse Atomic Power Department for the identical fuel elements [8] and for Carolinas-Virginia (CVTR) fuel elements of ___% enrichment which are the same except they are 8 feet instead of 4 feet long. Calculations of safe critical limits (multiplication factor of 0.8 or less) were made using the Westinghouse codes MUFT for fast group cross sections, SOFOCATE for the thermal spectrum, and the diffusion codes WANDA and PDQ. Calculations and experimental data were compared for seventeen different slightly enriched UO_2, water moderated, critical assemblies. The validation was found to be very good, so that high confidence may be placed in the calculations for the CVTR fuel rods when water moderated. The safe storage limits obtained for the worst case discussed above is ___ rods (calculations were based on infinitely long cylinders) or a safe cylinder diameter of 12 in.
Since the maximum number of rods which can be loaded in tray is 120 (with no wires, at a very unfavorable water to UO_2 ratio) and since the diagonal of the tray is only 7.8 in., it is evident that the actual multiplication factor of a tray will be much less than 0.8. Section 4.2.1 specifies a storage limit of ___ rods per tray, ____ Kg U-235 for the ____ w/o enrichment.

That the above storage limit is safe is confirmed by DP-1014[9], which gives a safe mass limit of ____ Kg U-235 and a safe infinite cylinder limit of 13.4" diameter, and by ANSI 16.1-1975[6], which gives similar values.

b. <u>1/4 inch diameter rods</u>

These are metal rods having enrichments of 1.016 w/o and 1.143 w/o U-235. Section 4.2.1 specifies a storage limit of ___ rods per tray, 1.67 Kg U-235 for the 1.143 w/o enrichment. Figures 13 and 15 of TID- 7016[4] give a safe mass limit of ___ Kg U-235 and a safe infinite cylinder diameter of 17" respectively. These values are confirmed by Figures 14 and 20 of HW-69273[10], after applying safety factors of 0.44 and 0.88 to the minimum critical mass and the minimum critical cylinder diameter respectively. While a brimful tray will hold ___ Kg U- 235, even this would permit double-batching, and the equivalent tray diameter is less than half the safe cylinder diameter.

c. <u>3/8 inch diameter rods</u>

These are metal rods having an enrichment of 0.___ w/o U-235. Section 4.2.1 specifies storage limits of ___ rods per tray, ___ Kg U-

235. Figures 13 and 15 of TID-7016[4] give a safe mass limit of __ Kg U-235 and a safe infinite cylinder diameter of 24" respectively. Again these values are confirmed by Figures 14 and 20 of HW-69273[10], after applying safety factors of 0.44 and 0.88 as above. While a brimful tray in these cases would contain a maximum of ___ Kg U-235, this would permit multiple batching, and the equivalent tray diameter is only one-third of the safe cylinder diameter.

15.3.2 Storage of License SNM-986 Material with Reactor Fuel

The storage limitation for License No. SNM-986 material with unirradiated reactor fuel was given in Section 4.2.3. Approval for the storage of reactor fuel with other SNM was given by NRC in the form of Amendment No. 21 (May 28, 1982) to Facility Operating License No. R-37, authorizing a change to Technical Specification 3.10-2. A description of the safe where the fuel and License SNM-986 material is jointly stored is given in the MITR-II SAR[2], paragraph 9.4.1.1.4. The method by which safe storage limits were determined for the License SNM-986 material is described in paragraph 9.4.1.2.4 of the SAR. The interior dimensions of the safe preclude storage there of any of the 48 inch rods of Item A.

15.3.3 Thermal-to-Fast Flux Converters

a) It was stated in Section 4.2.3(a) that the double contingency required for criticality in the 4 ft x 5 ft thermal column flux converter is flooding plus degradation of the safe geometry. Flooding is highly unlikely in the reactor containment building because there is no sprinkler system. Water would have to fill the entire basement and be over a foot deep on the main floor (about 50,000 cubic feet) before the converter would start to flood. This would require and uncontrolled, major leak in the water supply lasting several days, even if automatic alarms failed to summon assistance and sump pumps failed to operate.

The rods that are used in the converter assembly are UO_2 rods, 0.431" (pellet) diameter by 48" active length, having enrichments of ____% and/or ____%. These are assembled in a close packed (adjacent rods touching), triangular array not exceeding 7.6 inch thickness. The height will be limited by the rod length (four feet), and the width and thickness will be limited by the container design to 5 feet and 7.6 inches respectively.

A criticality safe, closely packed, slab geometry is maintained by installing the rods in a rigid container. The container is bolted to a cart that is rolled into an irradiation facility at the end of the

reactor thermal column. The container measures 64 5/8" wide x 53 1/4" high x 21 1/8" deep overall, and is constructed of type 6061-T6 aluminum. It has a 1" thick base plate, a frame of 1" x 1" bars and 1" x 1" x 1/4 angle, covered by 1/8" plate welded at the vertical and bottom seams.

The container cavity is partially or entirely filled with the UO_2 fuel rods and 4" x 4" x 49 1/2" graphite stringers. These are held in place by a lower grid plate, which lies on the bottom of the container, and by five upper grid plates which are bolted to supports in the container; 1/4" diameter, 1/4" long nipples on the fuel rods and graphite stringers fit into holes drilled in the grid plates. A cover plate seals the containers (while allowing equalization of pressure) and prevents lifting of the upper grid plates.

A normal loading of the converter assembly is ____ UO_2 fuel rods in 15 rows (approximately 2040 kg UO_2) and 30 graphite stringers in 2 rows, while the maximum loading is ____ UO_2 fuel rods in 17 rows, (approximately 2350 kg UO_2) and 45 graphite stringers in 3 rows. The maximum loading of the converter container will be:

____ kg UO_2
220 kg Aluminum clad
970 kg Graphite

Criticality is avoided by the close packing of the rods to limit moderation; V_{H2O}/V_{UO2} _ 0.21 in the event of flooding. A converter assembled entirely from ____% enriched rods in the form of an infinite array is far subcritical (K_∞ = 0.10 - 0.15). The US Atomic Energy Commission's original approval (August 22, 1969, Amendment No. 4 to License No. SNM-986) for assembly and use of this converter was based, for criticality safety, on Report WCAP-1373[8], which showed that Keff is less than 0.7 for closed-packed UO_2 fuel rods, 5% enriched U-235, pellet diameter 0.50 in., Zr clad, 0.58 in. OD, in the form of a 6 in. thick infinite slab. While converter lattice slabs up to 7.6" may be used, the size increase is more than compensated for by the decrease in enrichment from 5% to 2%. Assembly and disassembly of the converter will be done on the main floor inside the reactor containment building, which does not have fire sprinklers and only relatively small quantities of water in other systems. Therefore, the possibility of rearrangement of the rods into a more reactive array, with simultaneous flooding on the main floor of the reactor building, is not considered

credible. Criticality as a fast facility is not possible at this low enrichment (2%)

Criticality safety of this configuration can also be established on the basis of information in Report DP-1014[9]. The U-235 density for the converter is 116 g/L. For 108.92 g U-235/L, Appendix B of DP-1014 give interpolated values of 10.9 in. and 9.8 in. as the critical and safe thicknesses, respectively, of an infinite slab of 0.431 in. diameter unclad UO_2 rods, 2.00% U-235. This is a very conservative estimate for several reasons. Principally, the V_{H2O}/V_U used in the report for the above conditions is calculated to be 1.29, whereas the cladding in the converter array displaces 56% of the potential water, so that the actual V_{H2O}/V_U ratio is 0.44 (V_{H2O}/V_{UO2} = 0.21) in the unlikely event of flooding.

Further, though less important, DP-1014 values are for an infinite slab, neutron absorption by the cladding is ignored, and the actual U-235 density of____ g U-235/L would give a higher value for the safe slab thickness than the maximum value of ____ g U-235/L in the table. Non-conservative is the presence of graphite on one side of the array, but hand calculation indicates that this is a minor effect.

b) The existing flux converter in thermal column position 6CH1 employs an annular arrangement of 30 uranium oxide rods, 1.99 w/o enriched U-235, 4 feet long. The assembly contains _____ grams total U and 618 grams U-235. The safe mass limit for 2 w/o UO_2 lattices, flooded, is ____ kg U-235[6][9], and the critical mass is ____ kg U-235[9]. Thus, such an assembly would require multiple-batching and flooding to achieve criticality.

c) The flux converters are used in fixed positions in the reactor that are separated from each other by more than 12 in. between their closest points. This provides isolation in the event of flooding[4].

15.3.4 Reactor Physics

Since flooding is already assumed, the limitations imposed in Section 4.2.5 depend, for criticality safety, on the prevention of multiple-batching (about seven times). Degradation to a spherical geometry would require a slightly smaller accumulation for criticality, minimum critical mass ____ kg U-235 and safe mass limit ____ kg U-235[9]

15.3.5 Laboratory Solids and Solutions

Section 4.2.6 allows a maximum of____ g of U-235 in this category, which is intended to cover the variety of small items used in the many laboratories at the several MIT locations for the numerous activities described in Section 1.7. Assuming that all ___ g of U-235 is contained in a single spherical solution at optimum concentration, the material is still only 0.43 times a critical mass[4], and thus safe from double-batching.

Since the total amount of __% enriched uranium at the Institute (except for reactor fuel elements) is limited to ___g U-235, it is not credible that double-batching could occur even by inadvertent dumping into drain lines, followed by subsequent procurement and dumping of additional SNM. Disposal of waste is controlled through Reference 3, Attachment 11, Appendix 3, and the requirement for Accountability and Criticality Officer approvals of SNM disposal, liquid or solid. Any loss of SNM is investigated by the Accountability Officer before the transfer of additional SNM to the same user is authorized.

15.4 Validation of Calculations

The validation of calculational methods was discussed in those sections where applicable (15.3.1, 15.3.2, and 15.3.3).

15.5 Data Sources

These were referenced where data was quoted.

15.6 Fixed Poisons and Structural Integrity

The main activity where a fixed poison is employed for criticality control is in the storage of License SNM-986 material in the same array with reactor fuel. The array with its fixed cadmium poison is described in the MITR-II SAR, paragraph 9.4.1.1.4. After construction by MIT, thermal neutron transmission tests were conducted to verify the presence of cadmium.

The storage array for the low enriched fuel rods and the container for the 4 ft. x 5 ft. flux converter depend upon structural integrity to maintain safe geometry, one of the double-contingency factors in each case. The designs were developed by individuals having mechanical engineering training and reviewed by faculty members of the MIT Department of Nuclear Engineering. They were assembled by experienced technicians and shop personnel at the MIT Reactor, and have withstood normal handling without problems for over 30 years in the case of the storage

arrays and over 20 years for the flux converter. The trays in the storage array are supported at each end by steel frames. Three sides of the array are enclosed by the concrete vault walls, and the fourth is protected by a metal mesh, so that access to a tray is only from the one open end. We cannot envisage rods falling out of a tray or any credible accidents that would lead to structural failures having criticality safety significance.

Chapter 16: PROCESS DESCRIPTION AND SAFETY ANALYSES

16.1 Storage

Materials held under this license are stored as described below except when in use, when in criticality safe shipping containers, or when in temporary storage incident to use. All storage and use of SNM must be in accordance with the "Security Plan for the MIT Research Reactor Facility".

16.1.1 Special Nuclear Material

Most SNM under this license is stored in the vaults designated NW12-103 and NW12-105A in Figure I.2-2, in accordance with the limitations specified in paragraph 4.2.1. Some SNM may be stored with the reactor fuel in storage safe described in paragraph 9.4.1.1.4 of the SAR and additional amounts in a security file (fire and theft resistant four-drawer file)(2). Small items such as an irradiated fission chamber, may be stored in the hot plug storage area shown on Figure I.2-2, in a shielded hood or in a hot cell within the restricted area. Small quantities of SNM may be stored in other locations outside the reactor restricted area, provided that such storage is authorized by the RPC and meets the requirements of Reference 3, Attachment 11.

PuBe neutron sources (Item C) are stored in their shipping containers in a locked space within the reactor restricted area or in the secure area at the Bates facility.

16.1.2 Normal and Depleted Uranium

Normal and depleted U is stored in the vaults mentioned in paragraph 16.1.1. The 12 inch spacing from trays and containers of SNM is required for such storage.

Normal U slugs for the graphite exponential pile shown on Figure I.2-2 are normally stored in the pile or in one of the vaults. The pile is enclosed in a cadmium-aluminum envelope that is secured with a steel band in between physical inventories in order to discourage removal of the slugs.

Other normal and depleted U may be stored within the restricted area provided that it is adequately protected against unauthorized removal and adequately contained to prevent spread of contamination.

Normal and depleted U at other MIT locations is stored in accordance with the requirements of Reference 3, Attachment 11.

16.2 Process Description

Materials under this license are used for teaching and research purposes, none of which involve processing of the SNM or source material such as would occur in a fuel fabrication plant. Figure II.16-1 illustrates the reactor and shows the locations where the flux converters are used in the extension of the thermal column (designated "hohlraum"). The large converter (4 ft by 5 ft) is shown in greater detail in Figure II.16-2. Criticality analyses for the converters were provided in Section 15.3.3. These and analyses of other safety aspects of materials under this license, both at the reactor and elsewhere, are carried out in accordance with the established procedures described in Sections 2.3 and 2.7.

16.3 Description of Plutonium Materials

It is planned to retain three categories of materials containing Pu (Items C, D and E in Table I.1-1). The other Pu categories are to be disposed of as soon as practicable.

16.3.1 PuBe Neutron Sources

The plutonium in the neutron sources is in solid form alloyed with beryllium and encapsulated in a welded tantalum can which is re-encapsulated in a welded stainless steel can. The cans are slightly over one inch in diameter and one-three inches in length. They were fabricated by the Mound Laboratory of Monsanto Chemical Co. For the sources currently in inventory the nominal Pu weights, activities, and serial numbers are listed below:

Serial No.	Nominal Wt. (grams Pu)	Nominal Activity (Ci)
M52	16	1
M510	80	5
M1124	3	0.2
	99	

The isotopic content of the plutonium is not known.

16.3.2 Pu Alpha Sources

The plutonium in the alpha sources is in solid form, electro-deposited or a metal backing. The sources were manufactured by Eberline Instrument Corporation, have a maximum nominal activity for a single source of approximately 2 μCi (32 μg Pu). Fifteen sources have been acquired as of this date. As indicated in Table I.1-1, a possession limit of 80 μg (5 μCi) is proposed.

16.3.3 Pu Neutron Filters

The Pu in the neutron filters is in the form of a Pu-Al alloy, which is completely sealed in an Al case. The first two filters listed below were made at Argonne National Laboratory and the third at Nuclear Materials and Equipment Corporation, Apollo, Pennsylvania.

Filter No.	Pu (grams)
2	5.22
5	5.20
PNF-4-14	7.45

Chapter 17: ACCIDENT ANALYSES

17.1 Types of Accidents

Several types of accidents can be postulated that might involve the materials held under this license and lead to radiation concentrations and/or contamination levels affecting personnel either on-site or off-site or both. These include criticality, flood, fire and loss of encapsulation.

17.1.1 Accidental Criticality

Such an accident should never occur and is not possible outside of the reactor restricted area due to the possession limitation stated in Paragraph 4.1.1. Within the restricted area the double contingency requirements designed into each storage and use situation should again preclude such a possibility. If a criticality is postulated, however, experience(4) indicates that such a supercritical assembly will initiate local radiation alarms and may dismantle itself. Radiation levels and contamination will be hazardous to nearby individuals. Because it will occur in SNM having essentially a zero fission product burden initially, however, the release of radioactive materials to off-site locations and off-site radiation levels should be much less than the design basis accident postulated for the MIT Research Reactor and analyzed in the SAR, Section 5.3(2). The MITR Emergency Plan, Appendix 13A of the SAR, would be implemented for such an eventuality.

17.1.2 Flood

Gross flooding of any Cambridge location is not credible in view of the favorable hydrology, as described in SAR Section 2.4. Minor local flooding, e.g. building basements, should not create any problems in connection with use or storage of materials under this license, since most of it is in solid, non-dispersible form. The storage and use of such materials is planned so that flooding can be tolerated without criticality. Those materials not in solid, non-dispersible form are the laboratory solutions, Items B, H and L, and the UO_2 powder. Less than one millicurie is involved in each case, and decontamination would not be a major task.

17.1.3 Fire or Loss of Encapsulation

Failure of encapsulation could result in the dispersal of radioactive material, particularly in the event of a serious fire involving the material. Even under such circumstances, most materials are in a form that would limit dispersal.

Most of the U is in solid form, clad in aluminum, steel or zirconium (Items A, A-1, G and K and parts of B, H, I and L). About 33 Kg is unclad (Items F, J and M and portions of Items B, H, I and L). The aluminum cladding is probably of little consequence, however, since it would melt in a hot fire. The principal protection from fire lies in the almost complete coverage throughout the Institute afforded by automatic sprinkler systems (the reactor containment is an exception due to criticality considerations and its construction). Further protection is provided by the storage location (Vault NW12-103) and the graphite pile where the normal U slugs (Item G) are used. Both would protect the U from exposure to flames in the event of a surrounding fire.

If some of the U were exposed to fire, finely divided metal would probably burn. Solid rods and shapes for shielding would not [11][12], unless the fire were intense and prolonged, which is most unlikely due to lack of combustibles in sufficient quantity to fuel such a fire. Finally, that amount of U (enriched, normal or depleted) that might be dispersed in a fire (or in some other manner) could require some local decontamination, although this should not be a major task. Due to the low specific activity (only 2 Curies in 2800 Kg for all types of U combined) the contamination would not be a substantial hazard pending cleanup.

For Pu the specific activity is much higher and so is the hazard. However, the quantities will be much less (about 269 grams total at the reactor site), and the material to be retained Items C, D and E) is more reliably protected against dispersal. The PuBe neutron sources are an alloy of Pu and Be contained in a welded inner capsule made of tantalum, which in turn is sealed in a welded outer capsule made of stainless steel. The sources have an outer diameter of 1 inch and lengths of 1-3 inches. The tantalum capsule, with a melting point of 5425°F, would survive any industrial fire.

The Pu filters are a dilute alloy of Pu in Al, clad in Al. These are stored in thick-wall (1/8 inch minimum) steel, screw-top containers (melting point greater than 2500°F) designed to retain the contents in any industrial fire. When in use on a neutron spectrometer, they will not be protected by the steel but will be inside the reactor containment, whose exhaust air passes through HEPA filters. In the event of airborne contamination from a source such as a Pu filter, the building would be isolated by closing the ventilation dampers. It should be noted that the alloy of the Pu resists gross dispersion in the event of capsule failure except possibly after melting in a fire, in which case the reactor building would be sealed.

Cohen has reviewed the effects of Pu dispersal[13] and estimates that 18 grams of Pu would have to be dispersed in an average urban environment to cause a single eventual cancer fatality. Because of the encapsulation and conditions of storage or uses, the only credible dispersal of Pu would be an amount that is orders of magnitude less than the above figure.

APPENDIX 1

License SNM-986 Renewal Application

LEAK TESTING OF SEALED PLUTONIUM SOURCES

A. Each encapsulated plutonium source shall be tested for leakage at intervals not to exceed (6) months. In the absence of a certificate from a transferor indicating that a test has been made within six (6) months prior to the transfer, the sealed source shall not be put into use until tested.

B. The test shall be capable of detecting the presence of 0.005 microcurie of alpha contamination on the test sample. The test sample shall be taken from the source or from appropriate accessible surfaces of the device in which the sealed source is permanently or semipermanently mounted or stored. Records of leak test results shall be kept in units of microcuries and maintained for inspection by the Commission.

C. If the tests reveals the presence of 0.005 microcuries or more of removable alpha contamination, the licensee shall immediately withdraw the sealed source from sue and shall cause it to be decontaminated and repaired by a person appropriately licensed to make such repairs or to be disposed of in accordance with the Commission regulations. Within five (5) days after determining that any source has leaked, the licensee shall file a report with the Division of Fuel Cycle and Material Safety, U.S. Nuclear Regulatory Commission, Washington DC 20555, describing the source, the test results, the extent of contamination, the apparent or suspected cause of source failure, and the corrective action taken. The copy of the report shall be sent to the Director of the nearest NRC Regional Office of Inspection and Enforcement listed in Appendix D of Title 10, Code of Federal Regulations, Part 20.

D. The periodic leak test required by this condition does not apply to sealed sources that are stored and not being used. The sources excepted from this test shall be tested for leakage prior to any use or transfer to another person unless they have been leak tested within six (6) months prior to the date of use or transfer.

E. Notwithstanding the other provisions of this leak test condition, leak tests are not required on pacemakers implanted in experimental animals provided that a leak test shall be performed immediately following removal of the pacemakers from the animals.

APPENDIX 2

License SNM-986 Renewal Application

LEAK TESTING OF PLUTONIUM ALPHA SOURCES

A. The sources when not in use shall be stored in a closed container adequately designed and constructed to contain plutonium which might otherwise be released during storage.

B. At least once every three months the licensee shall test the source for loss of plutonium in one of the following ways, using radiation detection instrumentation capable of detecting 0.005 microcuries of alpha contamination:

(1) By measurement of the source of potential alpha contamination through surveys of the storage container and areas in which the source is used; or

(2) By wiping thoroughly the external surfaces of the source mount, other than the radioactive surface of the source, with a piece of filter paper of high wet strength and low porosity moistened with a solution which will not attack the mount and, after the paper is allowed to dry, measuring the radioactivity on the paper.

C. If any survey or measurement performed as required by B(1) or B(2) above discloses the loss of more than 0.005 microcurie of plutonium from the source, or if a source has been damaged or broken, the source shall be deemed to be losing plutonium. The licensee shall immediately withdraw it from use, and cause the source to be decontaminated and repaired, or disposed of in accordance with the Commission regulations. Within five (5) days after determining that any source has lost plutonium, the licensee shall file a report with the Division of Fuel Cycle and Material Safety, U.S. Nuclear Regulatory Commission, Washington DC 20555, describing the source, the test results, the extent of contamination and the corrective action taken. A copy of the report shall be sent to the Director of the nearest NRC Regional Office of Inspection and Enforcement listed in Appendix D of Title 10, Code of Federal Regulations, Part 20.

D. Records of test results shall be kept in units of microcuries and maintained for inspection by the Commission.

E. Notwithstanding the periodic test required by Paragraph B, any plutonium alpha source containing not more than 0.1 microcurie of plutonium is exempted from the above requirements.

Reactor Safeguard Committee

The primary concern of the Reactor Safeguard Committee is with matters of nuclear safety related to the MIT Research Reactor, including the safety of personnel on and off site. The committee reviews and approves all new operating plans and policies, all significant modifications thereto, and all new experiments involving significant changes in procedure prior to implementation. The committee verifies that nuclear reactor operation is consistent with MIT policy, rules, approved operating procedures, and license provisions.

Prof. J. David Litster, Chair (August 31, 2018)
Physics

Prof. Jacopo Buongiorno (August 31, 2017)
Nuclear Science and Engineering

Mr. Louis DiBerardinis *
Environment, Health & Safety Office

Prof. Benoit Forget (August 31, 2018)
Nuclear Science and Engineering

Dr. Charles W. Forsberg (August 31, 2017)
Nuclear Science and Engineering

Mr. John P. Foster *
Nuclear Reactor Laboratory

Mr. Mitchell S. Galanek *
Environment, Health & Safety Office

Dr. Joseph Kehayias ^ (August 31, 2017)
Tufts University

Mr. Francis X. Masse (August 31, 2017)
Emeritus, Environment, Health, and Safety Office

Prof. David E. Moncton *
Nuclear Reactor Laboratory

Mr. Sean O'Kelly ^ (August 31, 2017)
Idaho National Laboratory

Dr. Edward E. Pilat (August 31, 2017)
Nuclear Science and Engineering

Mr. Tom Sowdon ^ (August 31, 2017)
Entergy Corporation

Mr. Ronald M. Thurlow ^ (August 31, 2017)
Florida Power and Light

Ms. Susan S. D. Tucker #
Nuclear Reactor Laboratory

Prof. Maria Zuber *
Office of the Vice President for Research

Dr. William B. McCarthy *
Environment, Health & Safety Office

NOTE: Date in parentheses indicates term expiration.

LEGEND: * Ex Officio Voting ^ Non-MIT Member
Ex Officio Non-Voting L On Leave

APPENDIX 5

Committee on Radiation Protection 2016

The Committee on Radiation Protection is responsible for the establishment and continuing review of an adequate radiation protection program at the Institute and its off-campus sites. The committee is also responsible for the Institute's compliance with radiation protection regulations promulgated by state, federal, and local agencies.

Current Committee Membership

VOTING MEMBERS	DEPARTMENT	ROOM	TELEPHONE
Prof. Peter Dedon (Chair)	Biological Engineering	56-786	3-8017
Prof. Harold Hemond	Civil & Environ Eng.	48-311	3-1637
Prof. David Housman	Biology	E17-543	3-3013
Prof. David Bartel	WIBR	WI-601B	8-5287
Prof. Richard Milner	Physics	26-447	8-5639
Prof. Martin Polz	Civil & Environ Eng.	48-417	3-7128
Prof. Anne White	Nuclear Science & Eng.	NW17-111	3-8667
Prof. Joseph Formaggio	Physics	26-539	3-3817
Louis DiBerardinis	Environmental Medical	56-235	3-9389
Frank Massé	Radiation Protection	16-268	978-283-4888
William Donovan	WIBR	WI-101C	8-5104
Brian Primeau	Lincoln Lab	LL-S0-755E	781-981-2381
Michael Horton	Lincoln Lab	LL-S3-415	781-981-2857
Mark Whary	Comparative Medicine	16-825	3-9435
Mitchell Galanek (Executive Secretary)	Radiation Protection	N52-496	2-3477

EX-OFFICIO MEMBERS:

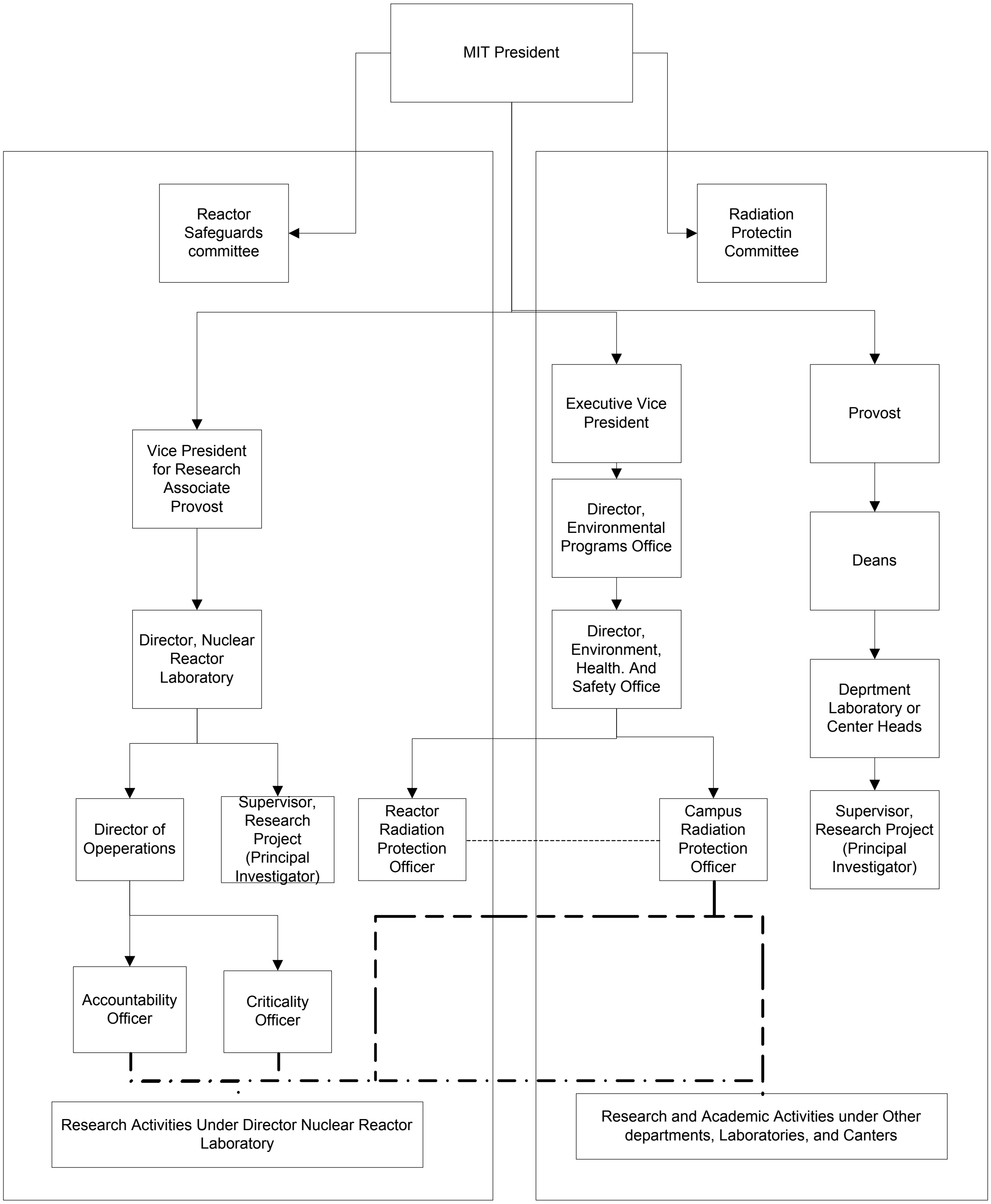
Fred McWilliams *	Radiation Protection	N52-496	2-3477
Ryan Toolin*	Radiation Protection	N52-496	2-3477
Judi Reilly*	Radiation Protection	N52-496	2-3477
Hans Richter*	Radiation Protection	N52-496	2-3477
Ryan Samz*	Radiation Protection	N52-496	2-3477
Dan Alexander*	Radiation Protection	N52-496	2-3477
Tina Dinh*	Radiation Protection	N52-496	2-3477
Matt Carey*	Radiation Protection	N52-496	2-3477
Bill McCarthy	Reactor Radiation Prot.	NW12-108	3-0346
Gerry Fallon	Bates Radiation Prot.	Bates Linac	3-9272

GRADUATE STUDENT REPRESENTATIVE:

Elizabeth Tolman	Physics

*** Non- voting Member of the Committee**

APPENDIX 6: ORGANIZATION



MIT Accountability Officer is accountable for all nuclear materials except by-product material

Campus Radiation Protection is accountable for all radioactive material except that held under license R-37 (which is the responsibility of Director of Reactor Operations

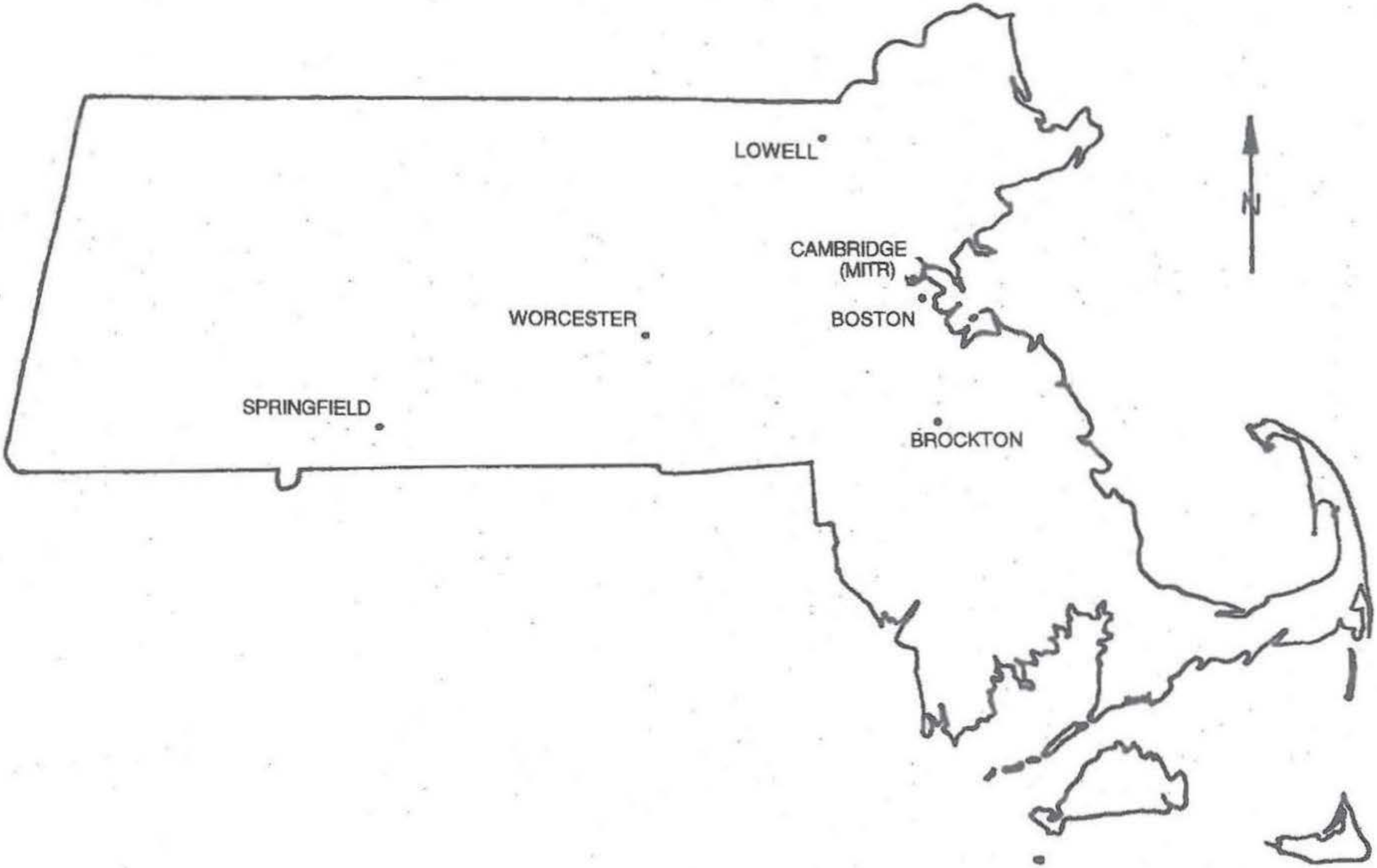


FIGURE 2-1 MASSACHUSETTS

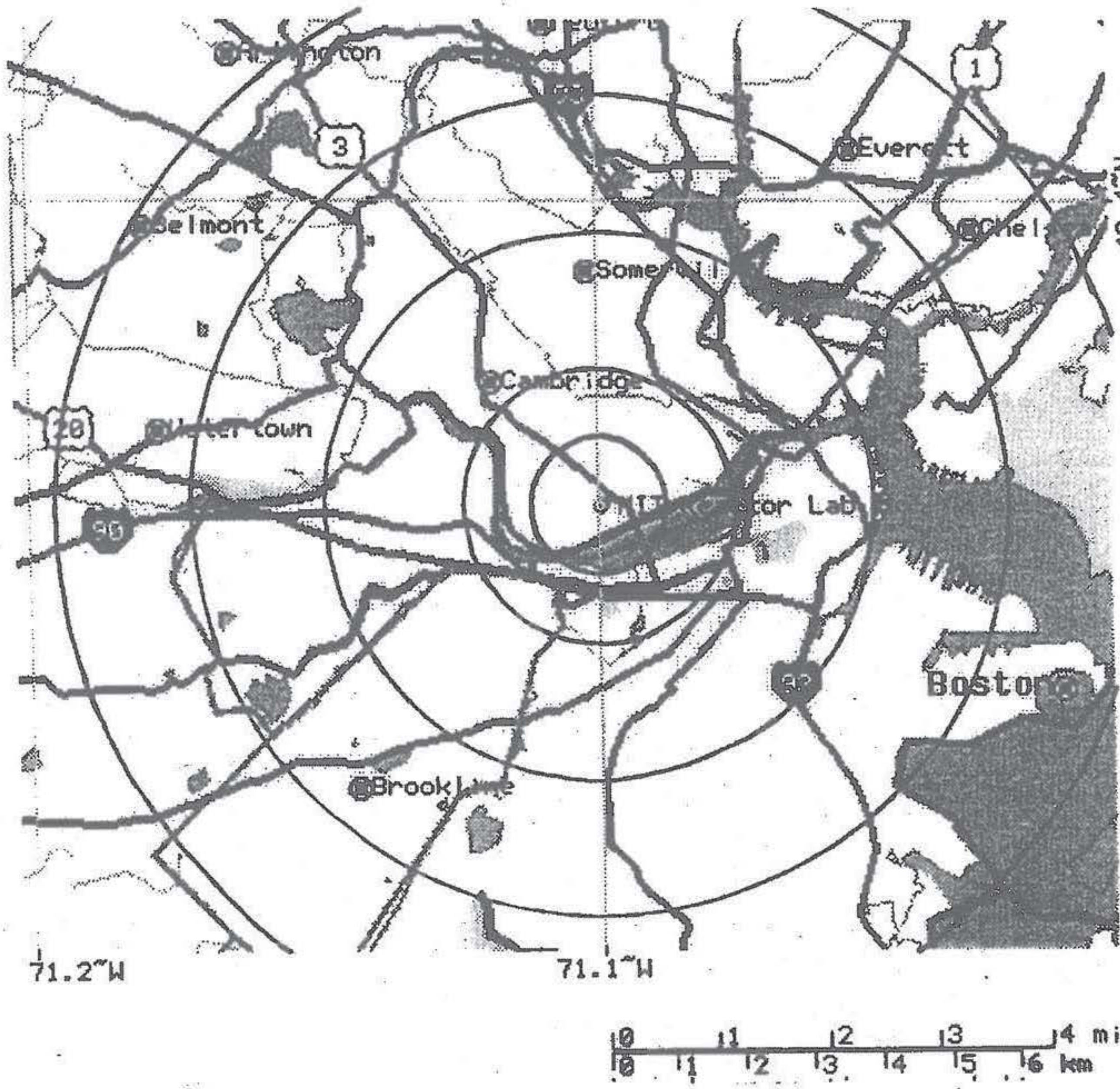


FIGURE 2-2 GREATER BOSTON AREA

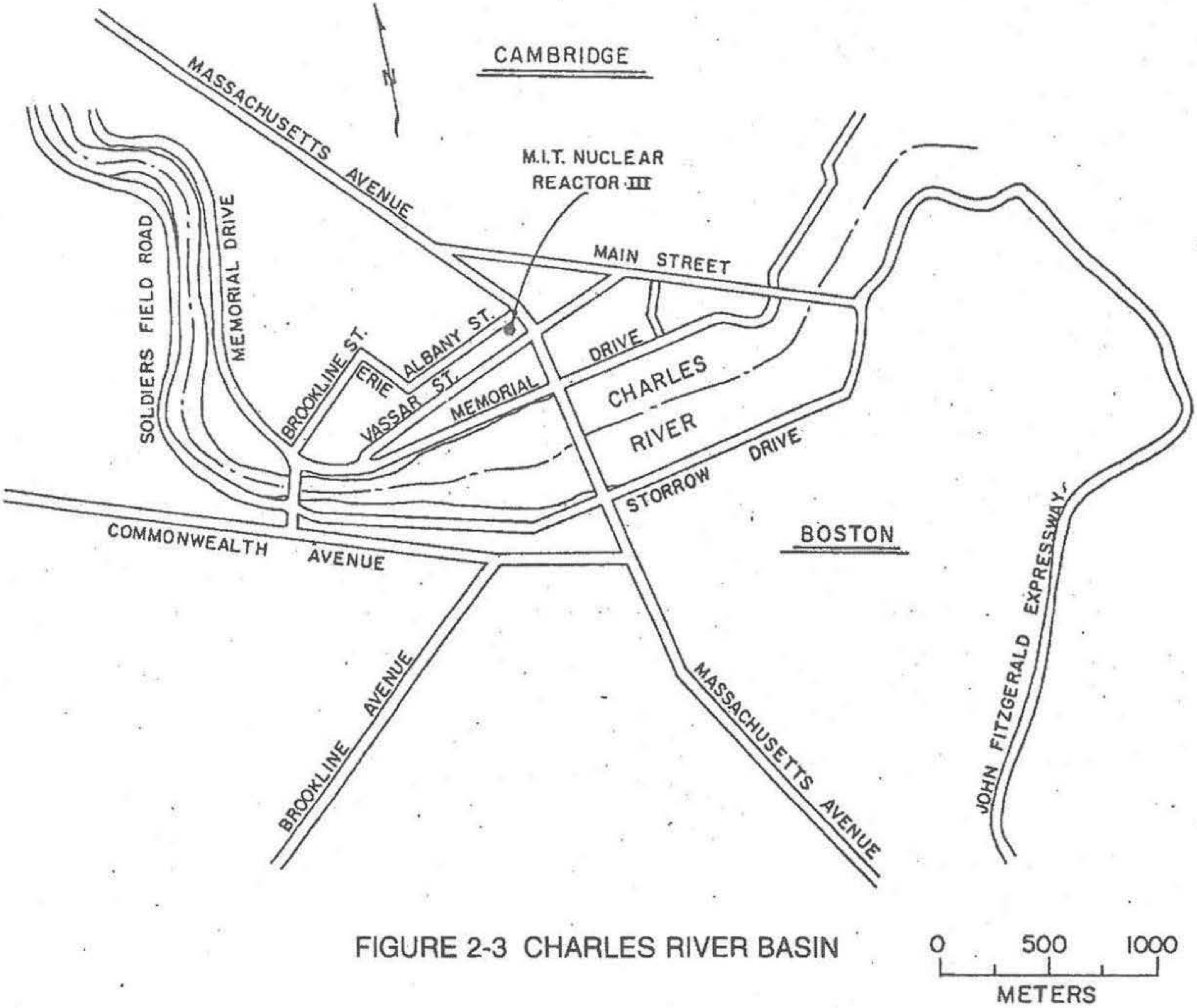


FIGURE 2-3 CHARLES RIVER BASIN

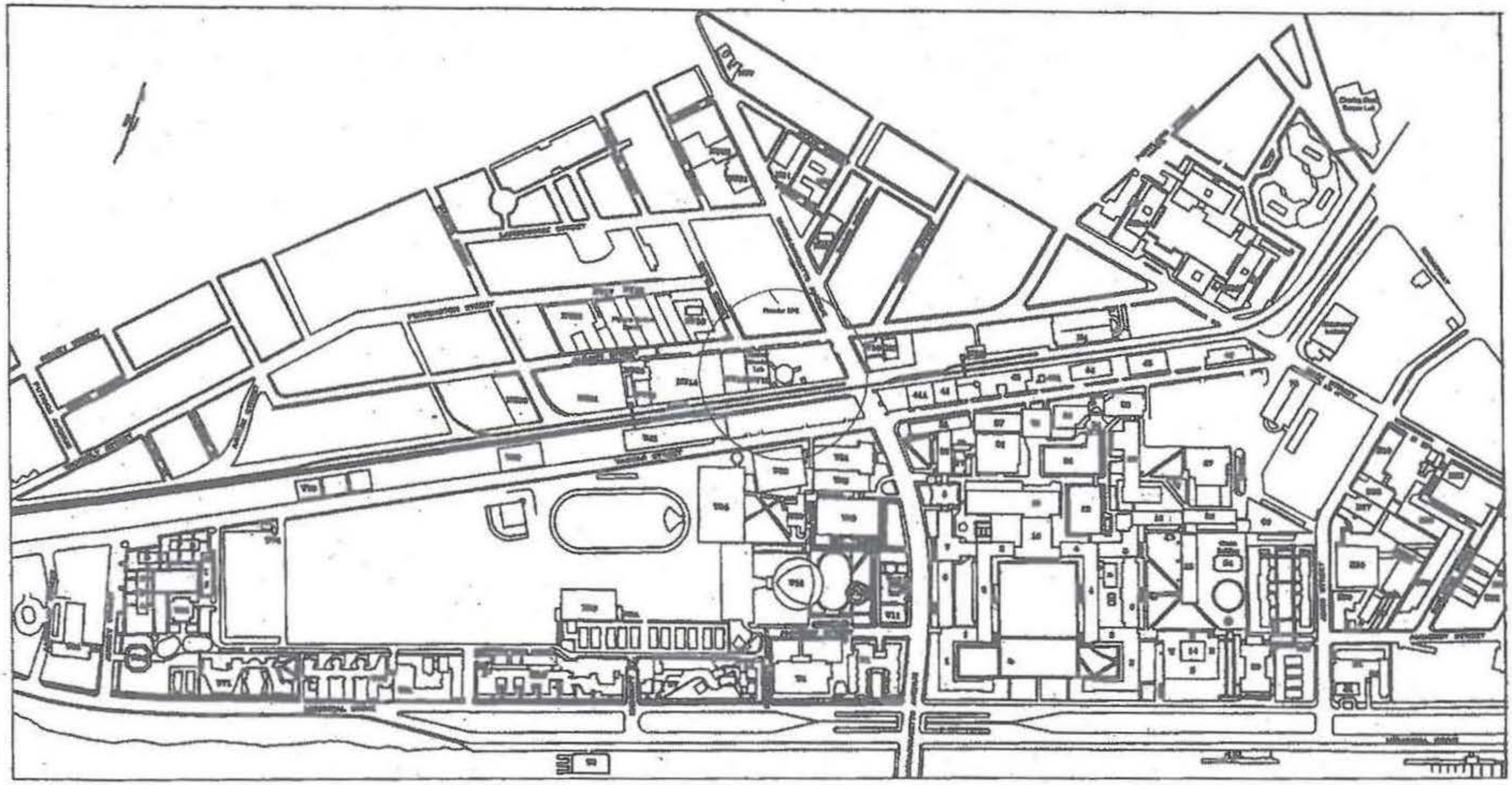


FIGURE 2-4 MIT CAMPUS

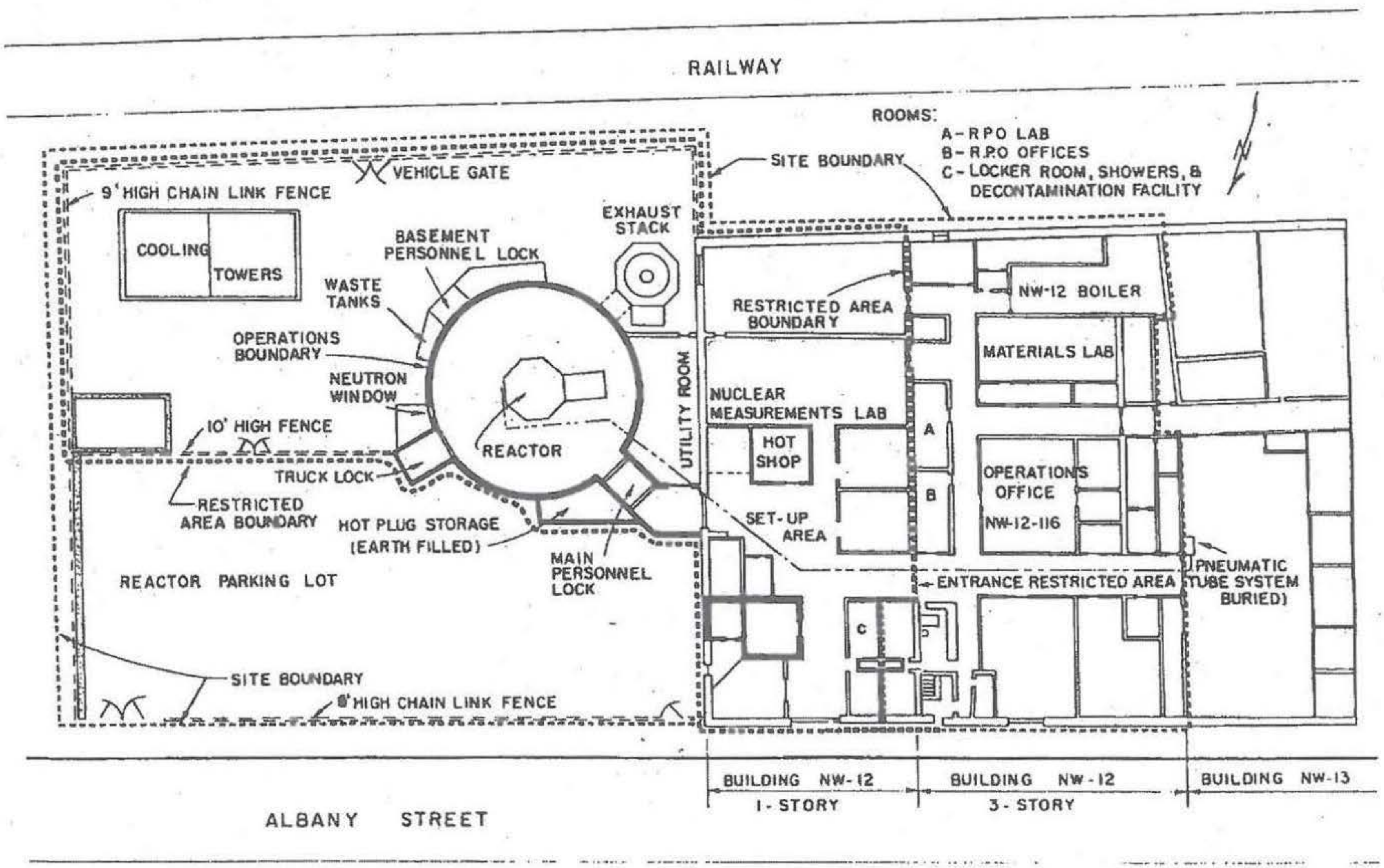


FIGURE 2-5 REACTOR OPERATIONS, RESTRICTED AREA, & SITE BOUNDARIES