SAFETY EVALUATION REPORT
DECOMMISSIONING OF THE CYCLOTRON FACILITY (BUILDING 140) AT NASA'S JOHN H. GLENN RESEARCH CENTER

1.0 BACKGROUND

In a letter dated, May 10, 2017, the licensee (National Aeronautics & Space Administration John H. Glenn Research Center (NASA Glenn)) submitted a request to amend license No. 34-00507-16 to release the NASA Cyclotron Facility, also known as Building 140, for unrestricted use. This building contained a cyclotron and activated metals, concrete, and other material, and is predominantly a below-grade (underground) structure. For the purpose of the Final Status survey, the licensee divided the Cyclotron Facility into two separate functional areas: the Cyclotron Vault, which housed the cyclotron, and Building 140 Auxiliary Rooms, which denotes all other areas of the Cyclotron Facility.

The cyclotron was constructed by General Electric in the 1940s and 1950s and was first operated in 1955. The cyclotron was upgraded in the 1970s from a 60" to a 69"-cyclotron. The facility was also upgraded several times to include neutron therapy and additional spacing. NASA operated the facility and cyclotron until 1990 for research purposes. Subsequently NASA contracted personnel from Leidos to support decommissioning of the facility. Leidos personnel have supported NASA with facility characterization and removal of activated and radioactively contaminated equipment and materials, except for the remaining cyclotron components, embedded piping, overhead crane, and building structures.

In 2015, the licensee took surface and subsurface soil samples around Building 140 to determine if significant radiological activation had occurred during cyclotron operation. Between 2015 and 2017, the licensee was regularly removing radiological activated material from the site and disposing of the material in accordance with NRC regulations. In February 2017, the licensee removed the cyclotron from the facility and disposed of it in accordance with NRC regulations. In May 2017, the licensee submitted Final Status Survey information for the site that demonstrated the basis for it being released for unrestricted use. The licensee might leave the building intact or might demolish the building and rubblize its contents.

2.0 SITE EVALUATION

A historical site assessment was performed by the licensee to determine what isotopes may be present at the site. The assessment included sampling of concrete and metal that could not be readily removed from the building as well as soil from outside the building.

The licensee operated the facility and cyclotron until 1990 for research purposes. Consequently, most radionuclides were of short half-life, less than 2 years, and had undergone approximately 15 half-lives.

The licensee developed 15 survey units where there would most likely be surface contamination associated with licensed activities. The licensee believes that, due to the length of time the cyclotron was inactive, the only nuclides of interest are Co-60, Eu-152, Eu-154, and Na-22.

The licensee took 119 core samples in the activated regions of concrete near the cyclotron (ML17159A744). The detected radionuclides include Co-60, Eu-152, Eu-154, and Na-22. Co-60 is the primary nuclide of concern for remaining cyclotron components, steel I-beams and rebar in the floor, and steel piping/equipment. The nuclide and maximum and average concentrations in picoCuries/gram (pCi/g) are listed in Table 1.

Table 1. Maximum and Average Radiological Conditions in Concrete

Nuclide	Maximum Concentration (pCi/g)	Average Concentration (pCi/g)
Co-60	1.38	0.42
Eu-152	4.97	1.45
Eu-154	0.3	0.3
Na-22	0.26	0.21

In 2015, 74 core samples, plus 2 quality control samples of the overburden soils immediately adjacent to the (underground) vault structure, were collected from 9 subsurface locations immediately above the Vault roof and 8 subsurface locations adjacent to the Vault exterior walls from the top of the structure to the footers (ML17159A729).

A total of 30 systematic surface soil samples, plus 2 quality control samples, were collected from 30 locations within the land area directly above the Cyclotron Facility (Building 140) (ML17159A744). All samples were analyzed by gamma spectroscopy and are identified in NASA Glenn; FSSR Bldg 140 – Attachment 6 – Soil Sampling Results Final (ML17270A113).

In the Building 140 Auxiliary Rooms, those areas outside of the Cyclotron Vault, no volumetric contamination as a result of cyclotron operations was found. Based upon historical information on these areas, as well as previous characterization results, these areas were divided into 15 survey units comprising 100% of the floor areas and lower walls up to 6 feet.

3.0 DOSE ASSESSMENT

3.1 Occupancy Scenario

3.1.1 SURFACE CONTAMINATION DOSE ASSESSMENT

The NRC reviewed the licensee's surface contamination and developed surface derived concentration guideline levels (DCGLs) based on two sources: (1) the default screening values provided in NUREG–1757, Vol. 2 Rev. 2, "Consolidated Decommissioning Guidance," (ML063000252) Table B.1, and (2) values calculated with the building occupancy scenario of the "DandD" code or model. NUREG–1757 Table B.1 values are provided for Co-60 and Na-22. Because screening values for Eu-152 and Eu-154 are not provided in that table, calculated values for Eu-152 and Eu-154 were developed for the building occupancy scenario and DandD using default parameters (see Table 2). Note that the screening values noted in Table 2 represent the maximum levels in disintegrations per minute per 100 square centimeters (dpm/100cm^2) that could individually be identified to show NRC's release criterion of 25 milliRem per year (mrem/yr) can be met.

Table 2. Surface Activity Default Screening Values

Nuclide	Default Screening Value (dpm/100 cm^2)
Co-60	7100
Eu-152	13000
Eu-154	11000
Na-22	9500

The licensee took gross beta measurements and identified the highest beta measurements were 1200 dpm/100 cm^2 with an average of 685 dpm/100 cm^2 (ML17174A910). Co-60 was not used because the metal components where the Co-60 is found are within the concrete structure and not subject to movement, and therefore identified as surface contamination, under normal circumstances.

Based upon the lowest default nuclide beta-emitting screening value (Na-22) and comparing it to the average beta measurement, 685 dpm/100 cm^2 the maximum dose an individual could receive is less than 10% of the release criterion of 25 mrem/yr.

3.1.2 <u>GENERAL RADIATION FIELDS (GAMMA)</u>

The licensee conducted radiological area surveys. Based upon the licensee's data, the average reading was only several micro-rem/hr above background with a high at two locations of 9 micro-rem/hr (ML17159A744). In a hypothetical conservative scenario where an individual would stay in the 4 micro-rem/hr field for approximately 2000 work hours in a year, that person would receive a maximum of 8 mrem/yr.

The NRC has determined that it is unlikely an individual will exceed the public dose limit based upon loose contamination and general radiation levels.

3.2 Alternate Scenarios

The licensee evaluated alternate scenarios to verify that residual contamination would not result in a dose limit being exceeded in a demolition scenario. NUREG–1640, Volume 1, "Radiological Assessments for Clearance of Materials from Nuclear Facilities" (ML032250178), considers a wide range of scenarios, including renovation, demolition, recycling, and disposal.

For each material (i.e., steel or concrete), the licensee chose the scenario from NUREG–1640 that yielded the highest dose using the mass-based, normalized mean for each radionuclide (Table 2.1 of NUREG–1640). The licensee used the scenario dose conversion factor provided in the NUREG to calculate a dose based on the highest measured concentration of each radionuclide in samples of concrete or steel.

The scenario dose conversion factors calculated in NUREG–1640 were based on the volume of concrete and steel resulting from decommissioning a nuclear power plant. These volumes were much larger than the volumes of contaminated material present in and around the cyclotron vault. Therefore, the licensee adjusted the estimated doses by the ratios of the masses of contaminated concrete and steel in the cyclotron vault to the concrete and steel masses used in NUREG–1640. In each calculation, the licensee conservatively chose the lowest volume used in the range of volumes considered in NUREG–1640 and an upper estimate of the volume of contaminated structural material in the cyclotron vault.

Table 3. Scenario Dose Conversion Factors (DCFs) and Critical Groups for Alternate Scenarios

Nuclide	Concrete		Steel	
	Mass-Based DCF (mrem/yr per pCi/g)	Critical Group	Mass-Based DCF (mrem/yr per pCi/g)	Critical Group
Co-60	1.07	Road Building	0.19	Scrap Yard
Na-22	0.89	Road Building	--	--
Fe-55	--	--	0.0000017	Scrap Yard
Ni-63	--	--	0.0000017	Scrap Yard
Eu-152	0.44	Road Building	--	--
Eu-154	0.52	Road Building	--	--

3.2.1 ACTIVATED CONCRETE DOSE ASSESSMENT

Since the licensee might not leave the building standing, but rather demolish the building and rubblize its contents, the licensee provided alternate scenarios that calculated the dose following clearance activities based on reuse of the steel or concrete using NUREG–1640. The generators of concrete rubble addressed in the study are NRC-licensed facilities: primarily commercial power plants, test and research reactors, and industrial nuclear facilities, much larger than the facility being evaluated here. To calculate doses in alternate scenarios, the licensee used the highest mass-based scenario DCF from NUREG–1640 adjusted for an applicable volume, with the highest concentrations using the mass–based, normalized mean of Co-60, Na-22, Eu-152, and Eu-154 in concrete samples from the site.

The licensee then corrected the mass–based, normalized mean based on the volume of concrete present versus the larger quantities of concrete used in the NUREG. The lower end of the range of the volumes considered in NUREG–1640 was 143,000 metric tons of concrete cleared in 1.7 years. Rounding 1.7 years to 2 years, the lower bound of the annual contaminated concrete removal rate used in the NUREG–1640 is 71,500 metric tons in 1 year. The licensee estimated that less than 550 metric tons of potential activated concrete remained at the site and adjusted the dose by a factor of 550 metric tons divided by 71,500 metric tons, or 0.8%. The licensee then reduced dose by a factor of 0.008 based on that volume correction. The NRC staff duplicated these calculations, confirming the licensee's results.

However, the NRC believes that the licensee's volume corrected dose is not appropriate to demonstrate compliance with the radiological criteria for unrestricted use of 10 CFR 20.1402 because of the potential underestimation of dose. Specifically, recycled contaminated material could also come from other facilities within the same batch load, increasing the total source term and leading to a general public dose that could be higher. In addition, the NUREG analysis was not based on a volume analysis, but rather on a mass of activity evenly distributed. A volume correction is not described. Therefore, the NRC did not consider the licensee's volume-corrected dose modeling in its technical review.

Because the licensee based the radionuclide concentrations on samples of concrete, the source term used by the licensee is appropriate for this calculation.

Although the calculations in NUREG–1640 involve many approximations, because the dose results were more than an order of magnitude below the 25 mrem/yr dose limit, adjustments of the approximations involved in the NUREG–1640 scenarios are unlikely to cause the estimated doses to exceed the dose limit. Therefore, the NRC staff determined this approach was adequate for demonstrating volumetrically contaminated concrete at the site would meet the 25 mrem/yr unrestricted use limit in these alternate scenarios.

Table 4. Alternate Scenario Dose Estimate for Volumetrically Contaminated Concrete

Nuclide	Average Activity Concentration (pCi/g)	Mass-Based Scenario DCF (mrem/hr per pCi/g)	Dose Using NUREG–1640 Volume Assumptions (mrem/yr)
Co-60	0.19	1.07	0.2
Na-22	0.04	0.89	0.04
Eu-152	1.07	0.44	0.47
Eu-154	0.18	0.52	0.09
		Total	0.80

3.2.2 ACTIVATED METAL DOSE ASSESSMENT

Since the licensee might not leave the building standing, but might demolish the building and rubblize its contents, the licensee provided alternate scenarios which calculated the dose following clearance activities based on reuse of the steel or concrete using NUREG–1640. The generators of steel addressed in the study are NRC-licensed facilities: primarily commercial power plants, test and research reactors, and industrial nuclear facilities, much larger than the facility being evaluated here. To calculate doses in alternate scenarios, the licensee used the highest mass-based scenario DCF from NUREG–1640 adjusted for an applicable volume, with the highest concentrations using the mass-based, normalized mean of Co-60 from steel samples from the site.

The licensee then corrected the mass-based, normalized mean based on the volume of steel present versus the larger quantities of steel used in the NUREG. The lower end of the range of volumes considered in NUREG–1640 was 15,000 metric tons of steel cleared in 1.7 years. Rounding 1.7 years to 2 years, the lower bound of the annual contaminated steel removal rate used in NUREG–1640 is 75,000 metric tons in 1 year. The licensee estimated that 70.3 metric tons of potential activated steel remained at the site, and adjusted the dose by a factor of 70.3 metric tons divided by 75,000 metric tons, or 0.09%. The NRC staff duplicated these calculations.

However, the NRC believes that the licensee's volume corrected dose is not appropriate to demonstrate compliance with the radiological criteria for unrestricted use of 10 CFR 20.1402 because of the potential underestimation of dose. Specifically, the recycling and disposal of the contaminated material could also come from other facilities within the same batch load, increasing the total source term and leading to a general public dose that could be significantly higher. In addition, the NUREG analysis was not based on a volume analysis, but rather on a mass of activity evenly distributed. A volume correction is not described. Therefore, the NRC did not consider the licensee's volume-corrected dose modeling in its technical review.

Because the licensee based the radionuclide concentrations on samples of steel, the source term used by the licensee is appropriate for this calculation.

For the same activity concentration, Co-60 contributes more than five orders of magnitude higher dose than Ni-63 or Fe-55. Therefore, Ni-63 and Fe-55 are not included in dose modeling calculations and Co-60 is the only nuclide of concern.

Table 5. Alternate Scenario Dose Estimate for Volumetrically Contaminated Steel

Nuclide	Average Activity Concentration (pCi/g)	Mass-Based Scenario DCF (mrem/hr per pCi/g)	Dose Using NUREG–1640 Volume Assumptions (mrem/yr)
Co-60	2.8 (weighted average)	0.19	0.53
		Total	0.53

Although the calculations in NUREG–1640 involve many approximations, because the dose results were more than an order of magnitude below the 25 mrem/yr dose limit, adjustments of the approximations are unlikely to cause the estimated doses to exceed the dose limit. Therefore, the NRC staff determined this approach was adequate for demonstrating volumetrically contaminated steel at the site would meet the 25 mrem/yr unrestricted release limit in these alternate scenarios.

3.3 Soil Dose Assessment

In 2015, the licensee took core soil samples of the overburden soils immediately adjacent to the Vault structure. Of the 74 core samples, there were only 8 locations of elevated measurements of Eu-152 above the Minimum Detectable Activity (MDA) of which the highest was 0.934 pCi/g (ML17270A116). Appendix B, Table B.2, titled "Screening Values (pCi/g) of Common Radionuclides for Soil Surface Contamination Levels," of NUREG–1757, Vol. 1, Rev. 2, lists

Eu-152 at 8.7 pCi/g as the maximum soil surface contamination that could be present to ensure the soil could be released pursuant to NRC regulations (i.e., 8.7 pCi/g of Eu-152 being equivalent to 25 mrem/yr). Using the Table B.2 Eu-152 screening value and using fractions of Eu-152 maximum contamination and the ratio of the number of core samples related to the number of samples that were above MDA for Eu-152, the NRC calculated less than 2.0% of the release limit, assuming all soil was uniformly distributed to a depth of 6 inches as defined in NUREG–1575, "Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)" (ML082470583).

The licensee's analysis of the 30 systematic surface soil sample collected from land area directly above the Cyclotron vault (Building 140) noted 8 locations and 1 location where Cs-137 and Eu-152, respectively, were identified as above the MDA (ML17270A113). For those 9 locations, the highest level noted of Cs-137 was 0.52 pCi/g and of Eu-152 was 0.964 pCi/g. The NUREG–1757, Table B.2, screening value for Cs-137 is 11 pCi/g and for Eu-152 is 8.7 pCi/g as the maximum soil surface contamination that could be present to ensure the soil could be released pursuant to NRC regulations. Using the Table B.2 Eu-152 and Cs-137 screening values, fractions of Eu-152 and Cs-137 maximum contamination and the ratio of the number of soil samples related to the samples that were above MDA for Eu-152 and Cs-137 and using the unity rule for those nuclides, the NRC calculated approximately 1.0 % of the release limit assuming the contamination was uniformly distributed to a depth of 6 inches.

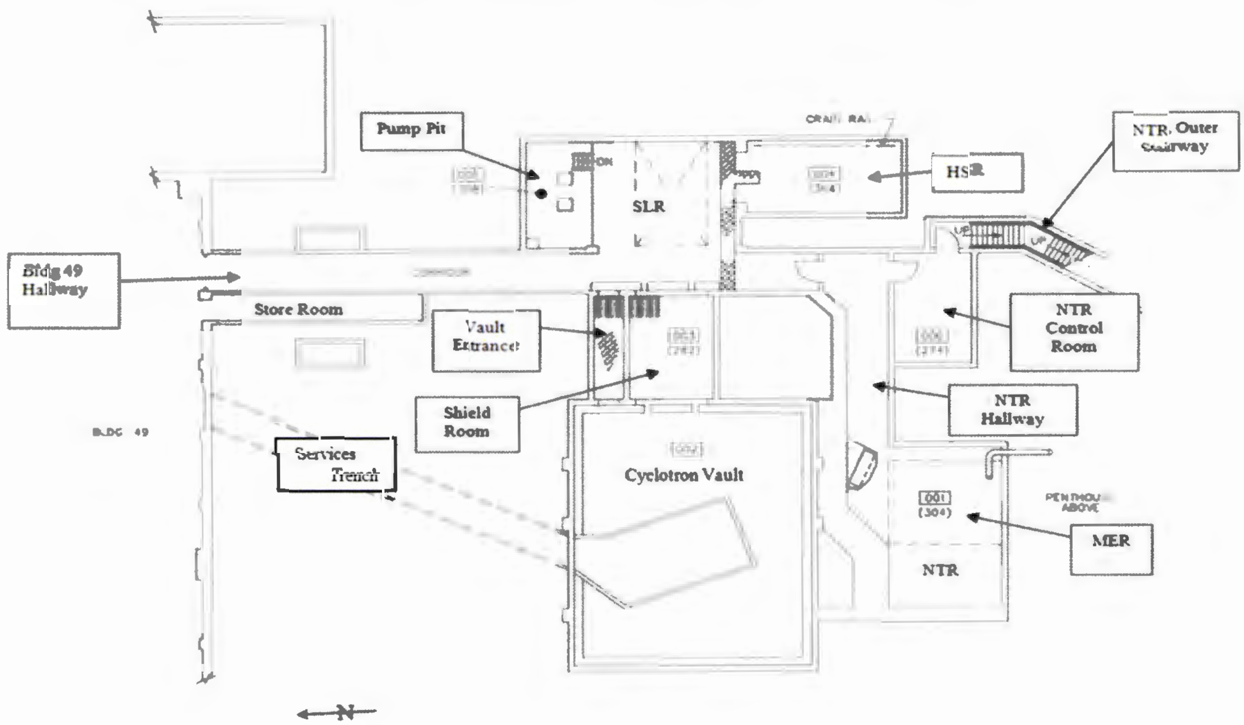

Figure 1 – Map of Building 140

4.0 STAFF REVIEW

The NRC evaluated four pathways of radiological contamination that could result in dose to members of the general public. Radiological pathways were dose associated with: activated concrete, activated steel, soil that surrounded Building 140, and residual surface contamination general radiation fields. The assessment also included, if the building is demolished, post-clearance of rubble for steel and concrete in future process streams for reuse.

Table 5. Dose Pathways to Members of the General Public

Dose Pathway	Estimated Public Dose Contribution (mrem/yr)
Activated Concrete	0.79
Activated Steel	0.53
Potentially Contaminated Soil	<1
Residual Surface Contamination / General Radiation Fields	<2.5 / 8 Total max of 10.5

Each dose pathway above represents a potential individual being exposed to residual radiation within the material and each pathway is independent of one another. The NRC's evaluation used the most reasonable conservative calculations based on guidance from NUREG–1575, NUREG–1757, and NUREG–1640 to determine radiological pathways and dose associated with residual contamination. In all cases, NRC's independent assessment determined that the doses to members of the public was a fraction of NRC's limits.

5.0 FINDINGS

Characterization results for the building and surrounding soil were consistent with the historical assessment. The concrete, metal, soil, and surface radiological sampling was sufficient to identify contamination present and the concentrations. The NRC independent dose assessment demonstrates that the public health and safety will be protected if the site is released for unrestricted use. Building 140 and the surrounding soils meet the unrestricted release criteria in 10 CFR 20.1402, and therefore, Building 140 and the surrounding soil can be removed from NASA license 34-00507-16.

6.0 REFERENCES

NRC "Standards for Protection Against Radiation," 10 CFR Part 20

Request to Remove Cyclotron Facility from License dated May 10, 2017 (ML17159A717)

Final Survey Report – NASA GRC Cyclotron Facility dated April 2017 (ML17159A729)

Final Survey Report – NASA GRC Cyclotron Facility Attachment 1 dated February 2017 (ML17159A733)

NASA Glenn Research Center Building 140 Cyclotron Vault Final Status Survey Report dated March 31, 2017 (ML17159A744)

NASA Glenn; FSSR Bldg 140 – Attachment 6 – Soil Sampling Results Final (ML17270A113)

NASA Glenn; FSSR Bldg 140 – Attachment 3 – Concrete Results Final (ML17270A111)

NASA Glenn; FSSR Bldg 140 – SR-10 Sub-Surface Soil Sample Close Out (ML17270A116)

Final Survey Report – NASA GRC Cyclotron Facility Attachment 1 dated April 2017 (ML17159A749)

NUREG–1757, Vol 2, Rev 2, "Consolidated Decommissioning Guidance" (ML063000252)

NUREG–1640, Vol 1, "Radiological Assessments for Clearance of Materials from Nuclear Facilities" (ML032250178)

NUREG–1640, Vol 2, "Radiological Assessments for Clearance of Materials from Nuclear Facilities – Appendices A thru E" (ML043090271)

NUREG–1640, Vol 3a, "Radiological Assessments for Clearance of Materials from Nuclear Facilities – Appendices F and G" (ML032250625)

NUREG–1640, Vol 3b, "Radiological Assessments for Clearance of Materials from Nuclear Facilities – Appendix G Results of Copper Scrap" (ML032250704)

NUREG 1640, Vol 4, "Radiological Assessments for Clearance of Materials from Nuclear Facilities – Appendices H thru O (ML041550973)

NUREG–1575, "Multi-Agency Radiation Survey and Site Investigation Manual" (MARSSIM) (ML082470583)

NUREG–1757, Vol. 1, Rev. 2, "Consolidated Decommissioning Guidance" (ML14093B263)

Inspection Report 030-05626/2017001 (ML17100A514)

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Pfizer Cyclotron TAR Response 25Sept2014 (ML14266A374)

Pfizer Cyclotron TAR Response 10Jul2014 (ML14189A111)