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RADIOLOGICAL ASSESSMENTS FOR THE NATIONAL IGNITION FACILITY*

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ABSTRACT

The potential radiological impacts of the National Ignition Facility (NIF), a proposed facility for fusion ignition and high-energy density experiments, were assessed for five candidate sites to assist in site selection. The GENII computer program was used to model releases of radionuclides during normal NIF operations and a postulated accident and to calculate radiation doses to the public. Health risks were estimated by converting the estimated doses into health effects using a standard cancer fatality risk factor. The greatest calculated radiation dose was less than one thousandth of a percent of the dose received from natural background radiation; no cancer fatalities would be expected to occur in the public as the result of normal NIF operations. The highest dose conservatively estimated to result from a postulated accident could lead to a one in one million risk of cancer.

INTRODUCTION

In the wake of the Nuclear Test Ban Treaty, the proposed National Ignition Facility (NIF), along with other facilities such as the Atlas Facility and the Contained Firing Facility, will be essential to ensuring the safety and reliability of the nation's existing stockpile of nuclear weapons. To support U.S. Department of Energy decision making for the siting of NIF pursuant to the National Environmental Policy Act, this paper presents the results of studies of the potential radiological impacts of NIF operations in various environmental settings including the preferred NIF site at Lawrence Livermore National Laboratory (LLNL) and alternative sites at Los Alamos National Laboratory (LANL), the Nevada Test Site (NTS), the North Las Vegas Facility (NLVF), and Sandia National Laboratories/New Mexico (SNL/NM).

NIF is classified as a low-hazard radiological facility. The goals of NIF are to achieve fusion ignition in the laboratory by using inertial confinement fusion (ICF) technology with an advanced-design solid-state laser and to conduct high-energy density experiments in support of national security and civilian applications. In the indirect-drive method of achieving ICF, target fuel capsules containing deuterium and tritium are imploded by soft x-rays generated by intense lasers. In the direct-drive method targets are directly heated and imploded by intense laser beams. NIF will be operated in one of two modes: conceptual design or enhanced. The conceptual design mode is the 192-beam indirect-drive operation. Under the enhanced mode, NIF is capable of both direct- and indirect-drive target experiments and can handle more experiments per year to accommodate greater user needs. Table 1 gives the estimated operating parameters for both operating modes of NIF.

The following sections identify the sources of radiation from NIF operations, describe the methods of estimating the potential radiation doses to the public from NIF, and present the results of the radiological assessments.

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DISCLAIMER

TABLE 1 Estimated Operating Parameters for the Conceptual Design and Enhanced Operating Modes of NIF

Operating Parameter	Operating Mode: Conceptual Design	Operating Mode: Enhanced
Maximum design yield (MJ)	20	20[a]
Annual total yield (MJ/yr)	385	1,200
Tritium throughput (Ci/yr)	600	1,750
Maximum tritium inventory (Ci)	300	500
Tritium effluent (Ci/yr)	10	30

[a] Maximum credible yield is 45 MJ for postulated accident evaluation.

SOURCES OF RADIATION

During normal NIF operations, several hundred fusion experiments would be conducted each year. These experiments would result in chronic atmospheric releases of small quantities of tritium and some radionuclides produced from activation of gases in the air. During a fusion experiment, each beam of light from a powerful multi-beamline laser would be focused and directed onto a target containing fusion fuel (a deuterium-tritium mixture). The fusion experiment would emit neutrons, energetic particles, debris, and x-rays. The energetic particles, debris, and x-rays would be confined by the 5-m (16-ft) inner-radius aluminum alloy target chamber. The 0.1-m (0.3-ft)-thick target chamber would be housed in a cylindrical reinforced-concrete building known as the Target Area Building, 30.5 m (100 ft) in diameter by 29.3 m (96-ft) tall. The target chamber would be surrounded by a 0.4-m (1.3-ft)-thick concrete shield. Most neutrons would travel through the target chamber and local shielding structure before being stopped by concrete walls. Some would activate the target chamber, gases in the air, and concrete and reinforcing bars (rebars) in the walls. The Target Area Building would have a 1.83-m (6.0-ft)-thick concrete wall and a 1.22-m (4.0-ft)-thick concrete roof to shield direct radiation of neutrons and their induced gamma rays. The adjacent switchyard building would have a 1.22-m (4.0-ft)-thick concrete wall and a 0.61-m (2.0-ft)-thick concrete roof. With such shielding design, direct radiation exposure to the general public would be negligible.[1] Most of the unburned tritium would be exhausted to a tritium processing system, while a small amount would be adsorbed onto the target chamber wall.

For impact analysis, a bounding accident was postulated on the basis of a preliminary hazard analysis. The bounding accident assumed that an earthquake of 1 g horizontal ground acceleration occurred during a maximum-credible-yield fusion experiment. With a small number of maximum-yield experiments projected for each year of NIF operation, the frequency of the accident would be lower than 2×10^{-8}/yr.[2] It was assumed that beamlines leading into the target chamber and building structures other than the Target Area Building would fail during the postulated earthquake. The collapsed beamlines and building structures would provide a pathway for acute atmospheric releases of tritium in the tritium processing system, activated gases in the air, and activated material in the target chamber. The released radionuclides would be dispersed and transported through air in patterns determined by meteorological conditions and would reach downwind humans directly or through the foods they ate. Potential radiological exposure pathways would include external exposure to airborne or ground-deposited radionuclides, inhalation of airborne radionuclides, and ingestion of ground-deposited radionuclides.

ASSESSMENT METHODS

The GENII computer program was used to model chronic and acute releases of radionuclides and to calculate radiation doses to the surrounding public at the five candidate sites during normal operations and under postulated accident conditions.[3] The GENII program models atmospheric dispersion of radionuclides with a straight-line Gaussian-plume model. The released radionuclides would be dispersed and transported through air according to meteorological conditions and reach downwind humans either directly or indirectly through the foods consumed. GENII calculates the effective dose equivalent (EDE) to a maximally exposed individual (MEI) and the collective EDE to the public. The MEI is defined as a member of the general public who could receive the maximum possible dose of radiation. Radiation doses calculated with GENII were converted into health effects on the basis of the *1990 Recommendations of the International Commission on Radiological Protection* (Publication 60).[4] The conversion factor is 5×10^{-4} cancer fatality per person-rem for the public.

Site-specific input into the GENII program includes population data, location of the MEI, source terms, meteorological data, and exposure pathway parameters such as consumption of plant food and animal products.

Population Data. Data from the 1990 census were used to derive population distributions around the candidate sites.[5] The population was spatially distributed on a circular grid with 16 directions and 10 radial distances up to 80 km (50 mi). The grid was centered on the proposed NIF location at each candidate site.

Location of Maximally Exposed Individual. Table 2 lists the distance and direction of the MEI relative to the proposed NIF location at each of the five candidate sites.

Source Term Data. Table 3 lists the source terms, or the quantities of radionuclides released to the environment over a period of time, for both the conceptual design and the enhanced modes of NIF operation. These source terms were used to estimate the impacts of normal operations and a postulated accident.

Meteorological Data. Site-specific meteorological data used in atmospheric dispersion calculations for releases from NIF at the five candidate sites were obtained from the meteorological tower at or near each site.

TABLE 2 Location of Maximally Exposed Individual for Each Proposed NIF Location

Site	Distance from Site (m)	Direction from Site
LLNL	400	E
LANL	1,620	NNE
NTS	20,000	SSW
NLVF	210	W
SNL/NM	1,864	N

TABLE 3 Radiological Source Terms

	Releases during Normal Operations (Ci/yr)[a]		Releases during Postulated Accident Conditions (Ci)[b]	
Radionuclide	Conceptual Design	Enhanced	Conceptual Design	Enhanced
Tritium	10	30	300	500
Nitrogen-13	21	86	7.9	24
Nitrogen-16	41	170	150	570
Sulfur-37	0.3	1.4	2×10^{-1}	6×10^{-1}
Chlorine-40	0.3	1.4	6×10^{-1}	1.7
Argon-41	17	54	1.4	3.3
Carbon-14	4.5×10^{-4}	1.5×10^{-3}	2.4×10^{-5}	5.5×10^{-5}

[a] Source: Singh et al. (1995).[1]

[b] Source: Brereton (1995).[2] The following radionuclides would also be released under the postulated accident conditions: sodium-24; magnesium-27; aluminum-28 and -29; vanadium-52; chromium-51 and -55; manganese-54 and -56; cobalt-58, -60, -60m, and -62m; nickel-57, copper-62, -64, and -66; zinc-63; platinum-197; gold-196 and -198.

RESULTS

Maximally Exposed Individual. Results of the radiological assessment are presented in Table 4. The annual doses to an MEI resulting from normal NIF operations at the five candidate sites with different environmental settings range from 0.0001 to 0.6 mrem, which are equivalent to 0.01% to 6% of the 10-mrem/yr limit specified by the Clean Air Act.

The Public. Results also indicate that collective radiation doses that could be received by the public at the five candidate sites range from 0.03 to 18 person-rem under the enhanced mode of operation for 30 years of planned NIF operation. For the conceptual design mode of operation, potential doses are about one-third those under the enhanced mode of operation. Although the estimated doses vary among candidate sites, they are inconsequential at any location. The greatest calculated radiation dose of 18 person-rem is less than one thousandth of a percent of the dose received from natural background radiation by the same population. No cancer fatalities would be expected to occur in the public due to normal NIF operations at any location.

Under postulated accident conditions, potential collective doses range from 70 to 4,900 person-rem during the enhanced operation mode and about one-half that during the conceptual design operation mode. The highest accident dose of 4,900 person-rem could result in two cancer fatalities; however, the frequency of the postulated accident is estimated to be 2×10^{-8} per year of NIF operation. Because it is extremely unlikely that such a postulated accident would occur, the probability of contracting one cancer fatality within the general public as a result of NIF operations is approximately one in a million.

REFERENCES

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TABLE 4 Results of Radiological Assessments for NIF Candidate Sites[a]

Parameter	LLNL	LANL	NTS	NLVF	SNL
Normal Operations					
Annual MEI dose (mrem/yr)	0.03 (0.1)	0.003 (0.01)	0.0001 (0.0003)	0.2 (0.6)	0.001 (0.003)
Percentage of 10 mrem/yr limit	0.3 (1)	0.03 (0.1)	0.001 (0.003)	2 (6)	0.01 (0.03)
30-year collective dose to the public (person-rem)	2 (6)	0.6 (2)	0.009 (0.03)	6 (18)	2 (6)
30-year cancer fatalities	None	None	None	None	None
Postulated Accident Conditions					
Collective dose to the public (person-rem)	260 (440)	290 (490)	41 (70)	3,000 (4,900)[b]	1,100 (1,800)
Cancer fatalities	None	None	None	1 (2)	0 (1)

[a] Values for enhanced mode of operation are given in parentheses.

[b] Higher public dose for NLVF is due to high population density near the site.

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