

CHAPTER 5

RADIOLOGICAL ASPECTS OF NUCLEAR - POWERED AIRCRAFT CARRIER HOMEPORTING

This section evaluates the radiological aspects of homeporting a CVN and related shore-based support facilities, and provides relevant information on the Naval Nuclear Propulsion Program (NNPP), which, pursuant to federal law, regulates radioactivity associated with Naval nuclear propulsion work. The policies of the NNPP are applied consistently to all locations where nuclear-powered ships are berthed or maintained.

This section has been developed making full use of the extensive body of unclassified environmental information available on nuclear propulsion matters. This information includes detailed annual reports published over three decades; independent environmental surveys performed by USEPA, by states in which NNPP facilities are located, and by some foreign countries; and a thorough independent review performed by the U.S. Government Accountability Office in 1991 (GAO 1991). The analyses summarized in this chapter are fully discussed in Appendix H, including input data and methodology, to facilitate independent verification of results.

Because nuclear propulsion technology is among the most sensitive military technologies possessed by the United States, Congress has placed stringent limitations on foreign access under the Atomic Energy Act of 1954 (amended) and other federal statutes. Appendix I, which is classified, contains Naval reactor design information and analysis of postulated accidents. The analysis of Appendix I supports the discussion of potential impacts presented in the unclassified portion of the EIS. However, all potential environmental impacts or conclusions discussed in Appendix I are covered in the unclassified sections of this EIS.

Chapter 9 of this EIS provides a list of abbreviations and acronyms and Appendix K provides a glossary of terms. Information on radiation exposure and risks associated with radiation exposure is contained in Appendix G. Appendix G provides information on radiation in general and includes discussions on background radiation and the risks as compared to some of the everyday hazards of life.

5.1 THE NNPP

5.1.1 History and Mission of the Program

In 1946, at the conclusion of World War II, Congress passed the Atomic Energy Act, which established the Atomic Energy Commission (AEC) to succeed the wartime Manhattan Project. In the Atomic Energy

Act, Congress gave the AEC sole responsibility for developing atomic energy. At that time, then captain (later Admiral) Hyman G. Rickover was assigned to the Navy Bureau of ships, the organization responsible for Naval ship design. Rickover recognized the military implications of successfully harnessing atomic power for submarine propulsion, and that it would be necessary for the Navy to work with the AEC to develop such a program. By 1949, Rickover had forged an arrangement between the AEC and the Navy that led to the formation of the NNPP.

In 1955, the nuclear submarine USS NAUTILUS put to sea and demonstrated the basis for all subsequent U.S. nuclear-powered warship designs. In the 1970s, government restructuring moved the NNPP from the AEC (which was disestablished) to what ultimately became the Department of Energy (DOE). As the NNPP grew in size over the years, it retained its dual responsibilities within the DOE and the Department of the Navy, and its basic organization, responsibilities and technical discipline have remained as they were when first established.

Today, the NNPP continues as a joint Navy/DOE organization responsible for all matters pertaining to Naval nuclear propulsion pursuant to Presidential Executive Order 12344, permanently enacted as Public Law 98-525 (42 U.S.C. 7158). As of July 2007, the NNPP is responsible for the following:

- The nuclear propulsion plants in 81 U.S. nuclear-powered ships.
- Two moored training ships located in Charleston, South Carolina used for Naval nuclear propulsion plant operator training.
- Nuclear work performed at six shipyards (four public and two private).
- Two DOE-owned, contractor-operated laboratories devoted solely to Naval nuclear propulsion research, development, and design work.
- Two land-based prototype Naval nuclear reactors used for research and development and for training Naval nuclear propulsion plant operators.

The NNPP's conservative design practices and stringent operating procedures have resulted in the demonstrated safety record of Naval nuclear propulsion plants. As of July 2007, U.S. Naval reactors have accumulated over 5900 reactor-years of operation and have steamed over 137 million miles and there has never been a reactor accident, nor any release of radioactivity that has had an adverse effect on human health or the quality of the environment. The following sections provide a detailed discussion of the

NNPP. For further information on this subject, see DOE/DOD 2006, Duncan 1990, and Hewlett and Duncan 1974.

5.1.2 Nuclear Propulsion for Navy Ships

The source of energy for powering a Naval nuclear ship originates from fissioning uranium atoms within the reactor core. Pressurized water circulating through a closed primary piping system transfers heat from the reactor core to a secondary steam system isolated from the reactor cooling water. The heat energy is then converted to mechanical energy to propel the ship, and provides electrical power to the rest of the ship.

Nuclear propulsion significantly enhances the military capability of aircraft carriers. Nuclear propulsion provides virtually unlimited high-speed endurance without dependence on tankers and their escorts. Moreover, the space normally required for propulsion fuel in oil-fired ships can be used for aircraft fuel in nuclear-powered ships. Because of these enhanced military capabilities, the older conventionally powered aircraft carriers (CVs) are being replaced by modern nuclear-powered aircraft carriers (CVNs).

5.1.3 Philosophy of the NNPP

Naval nuclear propulsion plants must be military capable and reliable in combat, as well as safe for the environment, the public, and those who operate and service them. The NNPP's success is based on strong central technical leadership, thorough training, conservatism in design and operating practices, and an understanding that in every aspect of the Program, excellence must be the norm. In addition, there is recognition that individuals must accept responsibility for their actions to maintain these standards. Admiral Rickover said it this way, "Responsibility is a unique concept: it can only reside and inhere in a single individual. You may share it with others, but your portion is not diminished. You may delegate it, but it is still with you. You may disclaim it, but you cannot divest yourself of it. Even if you do not recognize it or admit its presence, you cannot escape it. If responsibility is rightfully yours, no evasion, or ignorance or passing the blame can shift the burden to someone else. Unless you can point your finger at the person who is responsible when something goes wrong, then you have never had anyone really responsible."

Since radioactive material is an inherent by-product of the nuclear fission process, its control has been a central concern for the Navy's nuclear propulsion program since its inception. Radiation levels and releases of radioactivity have historically been controlled well below those permitted by national and international standards. All features of design, construction, operation, maintenance, and personnel

selection, training, and qualification have been oriented toward minimizing environmental effects and ensuring the health and safety of workers, ships' crew members, and the public. Conservative reactor safety design has, from the beginning, been a hallmark of the NNPP.

5.1.4 Safety Record of the NNPP

The history of safe operation of the Navy's nuclear-powered ships and their support facilities is a matter of public record. This record shows a long and extensive history of the NNPP's activities having no adverse effect on the environment. Detailed environmental monitoring results published yearly provide a comprehensive description of environmental performance for all NNPP facilities. Report NT-07-1 (NNPP 2007a) discusses the performance for all the ships, bases, and shipyards. This record confirms that the procedures used by the Navy to control radioactivity from U.S. Naval nuclear-powered ships and their support facilities are effective in protecting the environment and the health and safety of Sailors, workers and the general public.

NNPP reactor designs have received independent evaluations from the Nuclear Regulatory Commission (NRC) and the Advisory Commission on Reactor Safeguards (ACRS). These reviews were conducted as a means to provide confirmation and added assurance that nuclear propulsion plant design, operation, and maintenance pose no undue risk to public health and safety.

In addition, in 1991 the GAO completed a thorough 14-month review of DOE sites under the cognizance of the NNPP (GAO 1991). This review included full access to classified documents. The GAO investigators also made visits to the DOE laboratory and prototype sites supporting the NNPP, which operate to the same stringent standards imposed on Naval facilities and activities; and spent time on a nuclear-powered warship. The GAO review concentrated on environmental, health, and safety matters, including reactor safety. In congressional testimony on April 25 1991, the GAO stated in part:

In the past, we have testified many times before this committee regarding problems in the Department of Energy (DOE). It is a pleasure to be here today to discuss a positive program in DOE. In summary, Mr. Chairman, we have reviewed the environmental, health, and safety practices at the Naval Reactors laboratories and sites and have found no significant deficiencies.

The USEPA has conducted independent environmental monitoring in U.S. harbors during the past several decades. The results of these extensive, detailed surveys have been consistent with Navy results. These surveys have confirmed that U.S. Naval nuclear-powered ships and support facilities have had no

significant effect on the environment (USEPA 1998b, USEPA 1999d, USEPA 2001a, USEPA 2001b, USEPA 2003b, USEPA 2004, USEPA 2005a, USEPA 2005b).

The safety record of U.S. Naval nuclear propulsion plants aboard nuclear-powered warships is well known; there has never been a reactor accident in over 50 years since the first Naval reactor began operation, a record comprising over 5,900 reactor-years of experience. The NNPP currently operates 81 nuclear-powered warships (as of June 2007), one research vessel, two moored training ships, and two land-based prototypes powered by 102 Naval nuclear reactors. Since 1955, U.S. Naval nuclear-powered warships have steamed over 137 million miles. These ships have visited more than 150 ports in over 50 foreign countries and dependencies. There has never been any release of radioactivity that has had an adverse effect on the public or the environment.

U.S. nuclear-powered warships and their reactors are designed to exacting and rigorous standards. They are designed to survive wartime attack, include redundant systems and auxiliary means of propulsion, and are operated by highly trained crews using rigorously applied procedures. All of these features enhance reactor safety just as they contribute to the ability of the ship to survive attack in time of war.

Critical to safety are the officers and Sailors who operate the Naval nuclear propulsion plants aboard nuclear-powered warships. Since the 1950s, over 115,000 officers and enlisted technicians have been trained in the NNPP. The officer selection process accepts only applicants who have high standing at colleges and universities. All personnel receive 1 to 2 years of training in theoretical knowledge and practical experience on operating reactors that are like the reactors used on ships. Even after completing this training, before manning a nuclear propulsion plant watch station, the personnel must requalify on the ship to which they are assigned. In addition to the extensive training and qualification program, multiple layers of supervision and inspection are employed to ensure a high state of readiness and compliance with safety standards. When a ship's reactor is in operation at sea, there are both enlisted technicians and officers on duty, with an average total of 40 years of experience in Naval nuclear propulsion.

All U.S. Naval nuclear-powered warships use pressurized water reactors. The radioactive fission products are contained within high-integrity fuel elements that are designed to meet battle shock well in excess of 50 times the force of gravity. The fuel is designed to preclude release of fission products to the primary coolant. Only limited radioactivity is found in the pure water used in the all-welded primary coolant system. The principal sources of radioactivity in the pure water are trace amounts of corrosion and wear products from reactor plant metal surfaces in contact with this reactor water. The reactor compartment forms a container and shields the crew from radiation. This compartment is radiologically

clean so that it can be entered without any protective clothing within minutes of shutting down the reactor.

Substantial data exist verifying the high integrity of U.S. Naval reactor designs. Two nuclear-powered submarines (USS THRESHER and USS SCORPION) sank during operations at sea in the 1960s. Neither was lost due to a reactor accident, but both losses resulted in the ship exceeding crush depth and the hull being crushed inward by tremendous sea pressure. Radiological surveys of the debris sites have been performed on several occasions over the past three decades and confirm that, despite the catastrophic manner in which these ships were lost, no detectable radioactive fission products have been released into the environment. The only radioactivity found at these sites was from corrosion products from the primary coolant system. The amount of radioactivity found in the surveys was less than the naturally occurring radioactivity in the seabed sediment. These data are reported in detail and are available to the public (KAPL 2000).

In addition to the many safety considerations referred to above, several other factors enhance Naval reactor safety. Naval reactors are smaller and lower in power rating than typical commercial plants. Because naval reactors must fit aboard a warship, they are smaller and have a much lower power rating than commercial reactors. Also, since reactor power is directly linked to propulsion requirements, naval reactors typically operate at low power when the warship is in port, naval reactors are normally operated at very low power or shut down entirely. Their smaller size and the fact that they normally operate at low power or are shut down when in port mean that, in the highly unlikely event of a problem with the reactor, less than one percent (<1%) of the radioactivity contained in a typical commercial power reactor could be released from a naval reactor plant. The plant is designed to withstand a wide variety of casualty conditions without damage to the reactor core or release of significant amounts of radioactivity. Naval reactors are mobile and move through a source of unlimited seawater that can be used for emergency cooling and shielding if ever needed. In the event of a nuclear reactor accident, the ship can be rigged and towed away from populated areas, which, of course, is not the case for a fixed, land-based reactor. There are numerous ways to move a CVN including the use of its other reactor plant and the use of tugs or other tow craft. Sufficient time exists to support safe movement in the highly unlikely event of such an occurrence. Notwithstanding the remote possibility of occurrence, the potential range of postulated nuclear accidents has been analyzed and is discussed in Appendix I (classified).

Consistent with past practice, the CVN nuclear propulsion plant design was independently reviewed by the NRC (the Directorate of Licensing Division of the Atomic Energy Commission at the time) and the ACRS. These reviews concluded that CVN reactors can be safely operated.

5.2 NAVAL NUCLEAR-POWERED SHIPS

In Naval nuclear propulsion plants, fissioning of uranium atoms in the reactor core produces heat. Since the fission process also produces radiation, shielding is placed around the reactor to protect the crew. U.S. Naval nuclear propulsion plants, including CVNs, use a pressurized water reactor design that has two basic systems: the primary system and the secondary system. The arrangement is shown in Figure 5.2-1. The primary system circulates ordinary demineralized water in an all-welded, closed-loop system consisting of the reactor vessel, piping, pumps, and steam generators.

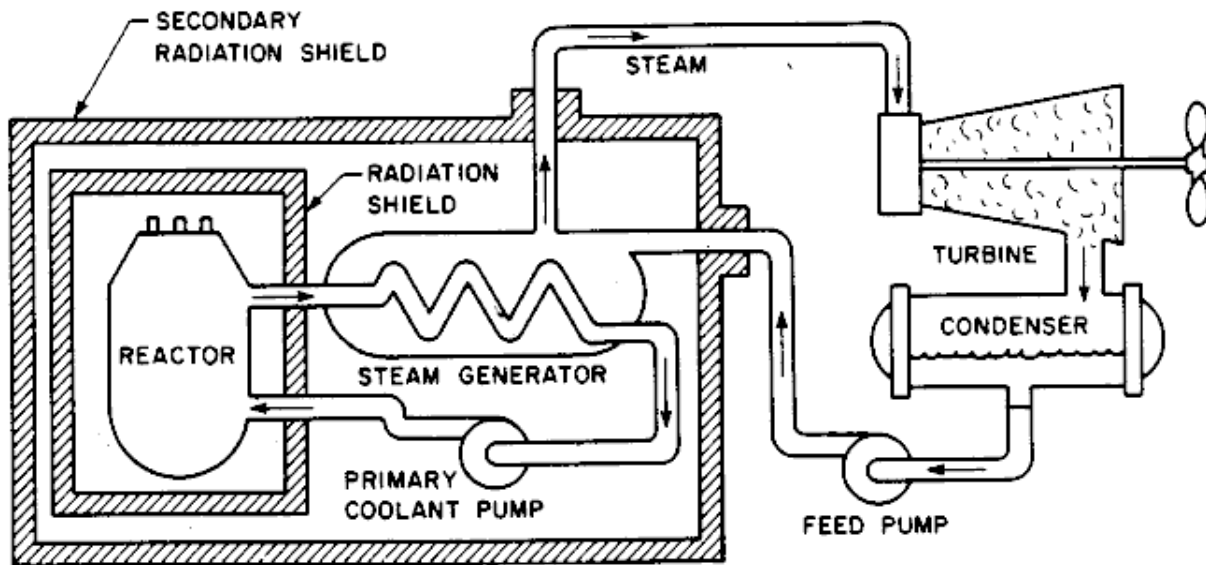


Figure 5.2-1 Pressurized Water Reactor

The heat produced in the reactor core is transferred to the water, which is kept under pressure to prevent boiling. The heated water passes through the steam generators where it transfers its energy. The primary water is then pumped back to the reactor to be heated again.

Inside the steam generators, the heat from the primary system is transferred across a watertight boundary to the water in the secondary system, also a closed loop. The secondary water, which is at a relatively low pressure, boils, creating steam. Isolation of the secondary system from the primary system prevents water in the two systems from intermixing, keeping radioactivity out of the secondary water.

In the secondary system, steam flows from the steam generators to drive the main propulsion turbines, which turn the ship's propellers, and the turbine generators, which supply the ship with electricity. After

passing through the turbines, the steam is condensed back into water and feed pumps return it to the steam generators for reuse. Thus, the primary and secondary systems are separate, closed systems in which constantly circulating water transforms energy produced in the nuclear chain reaction into useful work.

The reactor core is installed in a heavy-walled pressure vessel within a primary shield. This shield limits exposure from gamma and neutron radiation produced when the reactor is operating. Reactor plant piping systems are installed primarily inside a reactor compartment, which is surrounded by a secondary shield. Because of these two shields, the resulting radiation outside the propulsion plant spaces during reactor plant operation is generally not any greater than background radiation (NNPP 2007b).

5.2.1 Reactor Design and Operation

The design and operation of Naval nuclear-powered ships result in minimal risk of accidents, particularly while in port, and the consequences would be small should a problem occur. There are a number of reasons why this is so. A Naval reactor aboard a CVN is rated at only a fraction of the power of a commercial nuclear power plant. When a nuclear-powered aircraft carrier is moored in port, its reactor is normally shut down or operating at very low power levels since no power is required for propulsion. Since the plants are designed to accommodate significant transients to respond to the variable demands of warship propulsion while at sea, in-port operation is far less demanding on the plant. The plants must also meet stringent military requirements for shock and battle conditions, and are installed within strong hulls that also must meet stringent military requirements. The operators of Naval nuclear reactors are carefully selected, qualified to exacting standards, and trained to explicit procedures. Finally, the mobility of a ship provides for the removal of the problem source in the unlikely event of an accident.

The nuclear fuel in Naval nuclear propulsion reactor cores uses highly corrosion-resistant and highly radiation-resistant materials. The resistance to corrosion on the protective cladding of the fuel elements is so high that the corrosion rate is negligible. The reactor could remain submerged in seawater for centuries without releasing fission products while the radioactivity decays. As a result, the fuel is very strong and has very high integrity. The fuel is designed, built, and tested to ensure that the fuel construction will contain the radioactive fission products both during normal reactor operations and in more severe conditions such as extreme battle shock. Typical commercial nuclear power plants differ from Naval nuclear propulsion plants in fuel design. Civilian fuel is designed to meet the requirements of peacetime power production ashore. NRC regulations allow some release of fission products within regulatory limits under normal operations.

Naval nuclear fuel can withstand combat shock loads that are well in excess of 50 times the force of gravity, well in excess of the seismic loads a commercial plant might experience in a severe earthquake. Naval nuclear fuel routinely operates with rapid changes in power level since Naval ships must be able to change speed quickly. Naval nuclear fuel consists of solid components that are non-explosive, non-flammable, and non-corrosive. With the high integrity fuel design, fission products inside the fuel are never released into the primary coolant. This is one of the outstanding differences from commercial reactors, which normally have a small amount of fission products released from the fuel into the primary coolant.

Strict adherence to conservative principles of design and operation of Naval reactors was discussed on May 24, 1979, by the Director of Naval Nuclear Propulsion (then Admiral H. G. Rickover) in congressional testimony following the accident at Three Mile Island (House of Representatives 1979). Admiral Rickover emphasized that ensuring reactor safety is the responsibility of all personnel who work on Naval nuclear propulsion plants and that each NNPP element from training, to design, to construction, and to operation must be properly carried out in a coordinated fashion to achieve the goal of safe performance. A more thorough discussion of this topic can be found in the official history of the NNPP written by a member of the DOE historian's staff, Francis Duncan (*Rickover and the Nuclear Navy: The Discipline of Technology*, Duncan 1990).

5.3 FACILITIES THAT SUPPORT THE NNPP

The NNPP has set standards for construction of facilities that will be used to handle or store radioactive materials. These standards prevent the spread of contamination within the facilities or to the environment, minimize exposure to personnel within the facilities, ensure that exposure to personnel outside the facilities is negligible, and minimize the effort required to decontaminate and decommission the facilities. All aspects of facilities construction and future modifications are engineered.

5.3.1 Pre-Construction and Post-Construction Radiological Surveys

To provide a baseline for radiological information on radiological work facilities, radiation surveys of the building site, and analysis of soil and building construction material samples are performed. After construction, a radiological survey of the building is performed before any radiological work is allowed in the facility. The baseline data established by these surveys is retained to provide information needed for decommissioning the facility and returning it to its pre-radiological work condition.

5.3.2 Special Design Features

Standardized design features of NNPP radiological facilities have been developed to minimize the potential risk to the environment, the general public, and workers. These features are as follows:

- ***Impermeable Floors, Walls and Liquid Containment Curbs in Radiological Work Areas.***
The floors consist of a heavy structural concrete slab topped with an impermeable surface that eliminates the possibility of migration of liquid through the floor into the underlying soils. No underground piping is permitted in or under the floors. Wherever liquids are handled, containment curbs or basins are provided to contain the largest potential spill. All floors, walls, and ceilings are smooth, free of crevices, and sealed to aid in decontamination, if necessary. Walls and roofs are tightly constructed and sealed to minimize the sources of air leakage. Doors and windows are made to be as leak tight as possible. All entrances to the building are ramped or sealed, where practicable, to prevent any potential inadvertent loss of contaminated liquids. Consideration for hurricane storm surge effects will be factored into building design and site arrangement specifications.
- ***Radiation Shielding.*** The facilities are designed so that all exterior areas and interior non-radiological support areas have radiation levels so low that monitoring personnel for radiation exposure is not required. This is achieved by the use of radiation shielding integral to the permanent walls of the facilities as well as by the use of portable shielding as work conditions dictate.
- ***Mixed Waste is Segregated and Stored in a Dedicated Storage Area.*** Mixed waste (waste that is both radiologically contaminated and hazardous) is segregated into containers that hold similar (chemically compatible) wastes.

5.3.3 Decommissioning Facilities

Due to facility design and the control of radioactivity during operation, modern NNPP facilities can be decommissioned without any residual environmental impact. Within the past two decades, three shipyards involved in Naval nuclear work have been successfully radiologically deactivated and closed. Also, one Naval nuclear prototype site has been decommissioned and returned to the State of Connecticut for unrestricted use.

From 1958 to 1980, Ingalls shipbuilding was engaged in the construction and overhaul of Naval nuclear-powered ships in Pascagoula, Mississippi. The shipyard radiological facilities that supported this work were deactivated between 1980 and 1982 by removing and disposing of all radioactive material associated with Naval nuclear propulsion plants. Extensive radiological decommissioning surveys were performed on over 274,000 square feet of building and facility surfaces. Over 11,000 samples of these surfaces as well as soil, ground cover, and concrete were taken from all areas where radioactive work was previously performed. In addition, both the State of Mississippi and the USEPA performed independent surveys of these deactivated facilities. After these surveys were completed, the Ingalls facilities were released for unrestricted use.

As at Ingalls, extensive radiological decommissioning surveys were performed at the Mare Island and Charleston Naval shipyards to verify the removal of radioactive material. These shipyards were deactivated following the 1993 round of BRAC proceedings. At each shipyard, direct radiological surveys on over 5,000,000 sf of building and facility surfaces and analyses of over 40,000 samples of soil, ground cover, and concrete using sensitive laboratory equipment detected no cobalt-60 other than trace concentrations in a few localized areas. Simple, proven cleanup methods were used to remediate these areas. The total amount of NNPP radioactivity removed from the environment at each shipyard was equivalent to that in a single home smoke detector. Both shipyards were released for unrestricted use with respect to NNPP radioactivity by the operational closure date of April 1, 1996, with State and USEPA agreement.

The successful radiological deactivation and closure of the Ingalls, Mare Island, and Charleston shipyards demonstrate that the stringent control over radioactivity exercised by the NNPP from its inception has been successful in preventing significant radiological contamination of the environment. Personnel who subsequently occupy these facilities will not receive measurable radiation exposure above natural background levels that exist in areas not affected by Naval nuclear propulsion plant work (NNPP 2007a). Since the same standards would apply to servicing and homeporting a CVN at any location, there would be no significant short- or long-term environmental impact from those activities. More recently, in October of 2006, the U.S. NNPP commemorated the first-ever unrestricted release of a U.S. nuclear power reactor site based on the absence of both chemical and radiological constituents. After operation for 34 years and training over 14,000 Sailors, the Department of Energy S1C Prototype Reactor Site in Windsor, Connecticut, was returned to “green field” conditions. NNPP personnel and contractors worked in cooperation with the Connecticut Department of Environmental Protection, the USEPA, the town of Windsor, and the public to complete the project. These agencies also provided independent oversight of

the project. The current Windsor site condition makes it suitable for any future use, without restriction, from economic development to recreation.

5.4 RADIOLOGICAL IMPACT OF THE NNPP

The following discussions characterize the radiological impacts of all NNPP operations. This includes impacts due to both homeporting CVNs and operating related support facilities. As discussed below, the cumulative radiological impacts from all NNPP operations are very small and conservatively bound the impacts associated with CVN homeporting.

5.4.1 Source of Radioactivity

Nearly all (99 percent) of the radioactive atoms in a nuclear reactor are found in two forms: (1) the uranium fuel itself or (2) fission products created by the nuclear chain reaction. As discussed above, the fuel elements in Naval propulsion reactor cores are designed and built with high fuel integrity to retain this radioactivity. This high fuel integrity has been confirmed by operating experience and direct examination from spent cores. Such integrity is a necessity for Sailors who must live in the enclosed atmosphere of a nuclear-powered ship.

The remaining radioactive atoms present in a Naval nuclear reactor are encountered in two forms. The majority of the remaining radioactive atoms (99.9 percent of the remaining 1 percent) are part of the metal of the reactor plant piping and components. These radioactive atoms are created by neutron activation of iron and alloying elements during operation of the reactor plant. The balance (0.1 percent of the remaining 1 percent) is in the form of radioactive corrosion and wear products originating from metal surfaces in contact with reactor coolant. These corrosion and wear products are transported in the reactor coolant through the reactor core where they are activated by neutrons, and then deposited on piping system internal surfaces. Most of these corrosion products tightly adhere to piping system internal surfaces. The small amount that does not adhere is the source of potential radioactive contamination encountered during work on Naval nuclear reactor plants. Stringent controls are used to keep this material contained when working on system internals.

Corrosion and wear products in Naval nuclear reactor plants include the following radionuclides with half-lives of about 1 day or greater: tungsten-187, chromium-51, hafnium-181, iron-59, iron-55, nickel-63, niobium-95, zirconium-95, tantalum-182, manganese-54, cobalt-58, and cobalt-60. The predominant radionuclide is cobalt-60, which has a 5.2-year half-life and emits gamma radiation, which is one of the most penetrating forms of radiation. Cobalt-60 also has the most restrictive concentration limit in water

as listed by organizations that set radiological standards for these corrosion and wear radionuclides (CFR 2007; National Council on Radiation Protection and Measurements [NCRPM] 1959). Therefore, cobalt-60 is the primary radionuclide of interest for Naval nuclear propulsion plants.

5.4.2 Control of Radioactivity

Stringent radiological control practices are used in the NNPP. The effectiveness of these stringent radiological control practices has been proven and documented (NNPP 2007b). The following discussion outlines some of the NNPP's practices for controlling radioactivity.

5.4.2.1 Surface Contamination and Radioactive Liquid

Some of the most restrictive practices in the NNPP's radiological control program are those established for controlling radioactive contamination. The controls for radioactive contamination are so strict that precautions have sometimes been taken to prevent tracking contamination from fallout and natural sources into controlled radiological work areas. This is because the control limits used in the radiological work areas are well below the levels occurring outside in general public areas.

The basic approach in the NNPP is to avoid the need for anti-contamination clothing by containing radioactivity so personnel cannot come in contact with it. Another basic requirement of contamination control is monitoring all personnel leaving an area where radioactive contamination could possibly exist. This confirms that contamination has not been spread.

Work surfaces are designed to be easily cleanable (plastic or seamless sheet metal containments) to aid in fast and effective cleanup. Work surfaces are decontaminated during and after work to maintain positive contamination control. Frequent contamination surveys are conducted during work evolutions. Results of these surveys are reviewed by supervisory personnel to provide a double-check that no abnormal conditions exist. The instruments used for these surveys are checked for operability against a radioactive source daily, and they are calibrated at least every six months.

Radioactive liquids transferred from ships are placed in collection tanks and are processed at a dock-side processing facility. After processing the water to remove cobalt-60 and other particulate radioactivity, the water is returned to the ships for use or evaporated. This process has been proven effective in the NNPP's shipyards, operating bases, and other facilities.

5.4.2.2 Airborne Radioactivity

As noted, Naval fuel elements are designed to retain all fission products, including radioactive gases. Very minute amounts of fission products are created from fission that occurs naturally in trace amounts of uranium in the fuel cladding. Because these amounts are extremely small, there is no need for special equipment to remove or control fission products.

However, special controls are used in areas where radioactive corrosion and wear products could become airborne to prevent their reaching the environment. This radioactivity is controlled during maintenance so contamination is contained and respiratory equipment is not normally required. To prevent exposure of personnel to airborne radioactivity, and to prevent radioactivity from escaping to the atmosphere, work that might generate airborne contamination is performed inside sealed containments. These containments are ventilated to the atmosphere only through HEPA filters. Airborne radioactivity surveys are performed regularly in radioactive work areas. If airborne radioactivity above the limit is detected in occupied areas, work that might be causing airborne radioactivity is immediately stopped, and the potential source is identified and fixed.

Radiological work facilities have special design features to minimize the possibility of releasing airborne radioactivity to the surrounding atmosphere. These features include walls and roofs constructed and sealed to minimize the sources of air leakage, and doors and windows made to be as leak tight as possible. These same design techniques have been used at NNPP facilities to avoid significant environmental impact from radiological work.

The results of Air Particulate Sampler (APS) monitoring show that the average concentration of radioactivity and the total radioactivity in the air released from these facilities are consistently lower than that measured in ambient air away from the monitored facilities. In other words, there is less radioactivity in the filtered air exhausted from the facility than was originally in the air brought into the facility. Releases from these work facilities cause minute levels of radiation exposure far below that allowed by the USEPA in the Code of Federal Regulation (CFR 2006). These results clearly demonstrate that the design features historically used in the facilities are effective in preventing release of airborne radioactivity.

All liquid collection tanks used to store radioactivity are sealed by mechanical closures except for one penetration. This penetration vents any small pressure build-ups caused by filling or draining or by atmospheric changes. A HEPA filter on the penetration ensures that airborne radioactivity is retained in the tanks.

5.4.3 Radiological Control Practices

Besides the contamination control practices listed above, several other key radiological control practices used by the NNPP provide additional assurance that positive control of radioactivity is maintained. Among those NNPP-wide practices are the following:

- A radioactive materials accountability system is used to ensure that no radioactive material is lost or misplaced.
- All radioactive materials are specially packaged, sealed, and tagged with yellow and magenta tags bearing the standard radiation symbol and the measured radiation level. The use of yellow packaging material is reserved solely for radioactive material.
- Access to radiological facilities is controlled by trained radiological control personnel. In addition, all personnel entering radiological work and storage areas of the facilities are required to wear dosimetry devices.
- Only specially trained personnel are authorized to handle radioactive materials.
- Radiological surveys are conducted by qualified radiological control personnel inside and outside of facilities and ships where radiological materials are handled. This is a check to verify that the methods used to control radioactivity are effective.
- Written procedures are used to perform all radiological work. This not only ensures the work is carefully planned and documented, but also allows situation- specific radiological controls to be used. All written procedures are strictly adhered to word for word (i.e., verbatim compliance) in the NNPP. If this cannot be done, work is stopped until a change to the procedure is approved.
- Radioactive material or radioactive waste transported off-site is packaged and shipped per DOT regulations. Specially trained personnel accomplish this function.
- Technical problems encountered during radiological work are documented and corrected before work is allowed to continue.

5.4.3.1 Occupational Radiation Exposure

The NNPP invokes stringent controls on occupational radiation exposure. Radiation exposure levels resulting from these controls are discussed in detail in Appendix G, and they support the position that the analyses discussed later in this section are conservative. The NNPP's policy is to reduce to as low as reasonably achievable the exposure to personnel from ionizing radiation associated with Naval nuclear propulsion plants. These stringent controls on occupational radiation exposure have been successful.

The current Federal annual occupational exposure limit of 5 rem established in 1994 came 27 years after the Naval Nuclear Propulsion Program's annual exposure limit of 5 rem per year was established in 1967. (Until 1994, the Federal radiation exposure limit allowed an accumulation of exposure of 5 rem for each year of age beyond 18.) From 1968 to 1994, no civilian or military personnel in the Program exceeded its self-imposed tighter 5 rem annual limit, and no one has exceeded that Federal limit since then. In fact, no Program personnel have exceeded 40% of the Program's annual limit between 1980 and 2006 (i.e. no personnel have exceeded 2 rem in any of the last 27 years). And no civilian or military Program personnel have ever, in over 50 years of operation, exceeded the Federal lifetime limit.

No person in the NNPP has received greater than 2 rem in a year since 1980. The average occupational exposure of each person monitored since 1954 for radiation associated with Naval nuclear propulsion plants is 0.138 rem per year. For comparison, the amount of radiation exposure a typical person in the U.S. receives each year from natural background radiation is 0.3 rem. The total lifetime average radiation exposure from radiation associated with Naval nuclear propulsion plants for this 52 year period is 1.13 rem per person (NNPP 2007b).

In the late 1980s, the NCRPM reviewed occupational exposures to the U.S. working population (NCRPM 1989). This included a review of the occupational exposures to personnel from the NNPP. Based on this review, the NCRPM concluded: "These small values (of occupational exposure) reflect the success of the Navy's efforts to keep doses as low as reasonably achievable."

5.4.3.2 Radioactive Solid Waste Disposal

The amount of low-level radioactive solid waste generated during Naval ship and maintenance facility operations is small in comparison to other waste generators. This waste includes radioactively contaminated rags, plastic bags, paper, filters, ion exchange resin, and scrap materials resulting from work aboard ship and in the shore-side support facilities. Liquids that cannot be processed for reuse are solidified and properly disposed of. This waste is packaged in DOT-approved containers, shielded if

necessary and accumulated in a controlled storage area until it can be shipped for disposal at a burial site that is licensed either by the NRC or by a State under agreement with the NRC.

The annual volume of solid low-level radioactive waste generated by all Naval nuclear-powered ships and their support facilities in 2005 is about 0.5 percent of the total volume disposed of at U.S. commercial disposal sites (NNPP 2007a). The amount of radioactive waste that would be generated by the Navy at CVN homeport facilities would be a small fraction of the Navy total.

5.4.3.3 Mixed Hazardous and Radioactive Waste

Hazardous waste is waste that poses a potential threat to human health or the environment if not properly managed. These substances can be toxic, corrosive, ignitable, or chemically reactive (note that this does not include radioactive substances regulated under the Atomic Energy Act). Radioactive waste is a waste that contains radionuclides regulated under the Atomic Energy Act. Mixed waste generated as a result of NNPP activities is a mixture of chemically hazardous waste and low-level radioactive waste. Within the NNPP, concerted efforts are taken to prevent commingling radioactive and chemically hazardous substances to minimize the potential for generation of mixed waste. Examples of these efforts include avoiding the use of hazardous solvents, lead-based paints, and lead shielding in disposal containers. As a result of NNPP efforts to avoid the use of chemically hazardous substances in radiological work, NNPP activities typically generate each year less than 20 cubic meters of mixed waste that requires offsite treatment following completion of onsite processing. Small quantities of mixed waste generated as a result of NNPP activities at NAVSTA Mayport would be stored in accordance with federal and state hazardous waste regulations. Limited treatment allowed by generators of hazardous waste may be performed on some mixed wastes. This treatment would be performed in accordance with federal and state regulations. Mixed wastes would be stored on-site pending off-site shipments for treatment and disposal. Due to the small quantities generated of mixed waste that would be generated at NAVSTA Mayport, these wastes would be expected to be stored for greater than 90 days to facilitate efficient operations, therefore a modification to the existing permit for storage of hazardous waste at NAVSTA Mayport would be requested to allow storage of the mixed waste. Implementing the proposed action would not result in an increase in the total amount of mixed waste generated as a result of NNPP worldwide activities. Moreover, detailed characterization of NNPP mixed waste has been accomplished using sampling and extensive process knowledge, and has confirmed that the waste is suitable for safe storage until it is shipped off site for treatment and disposal (NNPP 2007a).

5.4.3.4 Radioactive Material Transportation

Only specially trained, designated people who are knowledgeable in shipping regulations are permitted to authorize shipments of radioactive material. Special transportation services, such as signature security service or sealed shipping vehicles used exclusively to transport radioactive material, ensure point-to-point control and traceability are maintained from shipper to receiver.

Shipments of radioactive material in the NNPP are made per regulations of the DOT, DOE, and NRC. These regulations ensure shipments of radioactive material are controlled to protect the environment and the health and safety of the general public, regardless of the transportation route taken.

Shipments of radioactive material associated with Naval nuclear propulsion plants have not resulted in any measurable release of radioactivity to the environment. There have never been any accidents involving a significant release of radioactivity during shipment of NNPP radioactive waste. In particular, the NNPP has shipped low-level radioactive material since the 1950s with no release of radioactivity.

Estimates of annual radiation exposure to transportation crews and the general public from shipments of radioactive material have been made in a manner consistent with that used by the NRC (ANSR 2002). As discussed in reference NNPP 2007a, NNPP shipments have not resulted in any significant exposure to the general population. The maximum exposure to any individual member of the public is far less than that received from natural background radioactivity.

5.4.4 Radiological Environmental Monitoring Program

To provide additional assurance that procedures used by the U.S. Navy to control radioactivity are adequate to protect the environment, the Navy conducts environmental monitoring in harbors frequented by its nuclear-powered ships. Environmental monitoring surveys for radioactivity are periodically performed in harbors where U.S. naval nuclear-powered ships are built or overhauled and where these ships have homeports or operating bases. Samples from each harbor monitored are also checked at least annually by a DOE laboratory to provide a further check on the quality of the environmental sample analyses as a check of Navy results. The DOE laboratory findings have been consistent with those of the shipyards.

5.4.4.1 Marine Monitoring

Marine monitoring consists of analyzing harbor water, sediment, and marine life for radioactivity associated with Naval nuclear propulsion plants. This monitoring is supplemented by shoreline surveys.

Sampling harbor water and sediment each quarter year is emphasized since these materials would be the most likely to be affected by releases of radioactivity.

Sediment samples are collected and analyzed specifically for the presence of cobalt-60, which, as discussed earlier, is the predominant radionuclide of environmental interest resulting from Naval nuclear reactor operations. Sampling points are selected to form a pattern around ship berthing locations and to provide points in areas away from berthing locations. These sampling points consider characteristics of the harbor. Summary of 2006 surveys for cobalt-60 sampling show that most harbors do not have detectable levels of cobalt-60 in sediment. The detectable level of cobalt-60 for Navy radiological surveys is 0.01 picocuries per gram. The actual value varies depending on the amount of naturally occurring radioactivity in the survey sample. Low levels of cobalt-60, less than three millionths of a microcurie per gram, are detected around a few operating base and shipyard piers where nuclear-powered ship maintenance and overhauls were conducted in the early 1960s. These low levels are well below the naturally occurring radioactivity levels in these harbors. A measure of significance of these low levels is that if all of a person's food were to contain three millionths of a microcurie of cobalt-60 per gram, that person would receive less than 10 percent of the annual dose one gets from natural background radiation. Since 1970, nuclear-powered warship operations have not caused any increase in the general background radioactivity in the environment.

Harbor water samples are taken once each quarter in areas where nuclear-powered ships are berthed, and from upstream and downstream locations. No cobalt-60 has been detected in any of the water samples from all the harbors monitored.

Marine-life samples, such as mollusks, crustaceans, and plants, have been taken from all harbors monitored. No buildup of cobalt-60 has been detected in these samples of marine life.

Shoreline areas uncovered at low tide are surveyed with sensitive gamma scintillation detectors to determine if any radioactivity from bottom sediment has washed ashore. The results of these surveys are consistent with natural background radiation levels in these regions. Thus, there is no evidence that these areas are being affected by nuclear-powered ship operations.

5.4.4.2 Air Monitoring

Naval nuclear reactors and their support facilities are designed to ensure that discharges of radioactivity are well below USEPA regulatory limits (CFR 2006) in airborne exhausts. Radiological controls such as the use of containments, special ventilation, frequent radiological monitoring when work is in progress,

frequent decontamination of work containments to maintain positive control of radioactive contamination, and HEPA filtration systems serve to prevent significant radioactivity from becoming airborne. The total air emission from any facility and its co-located ships is less than 1 percent of the applicable USEPA (CFR 2006) limits. In fact, comparison of sensitive radioactivity measurements in shipyards demonstrates that air exhausted from Naval nuclear propulsion facilities contained a smaller amount of radioactivity than was present in the ambient air outside the facilities.

5.4.4.3 Perimeter Monitoring

Ambient radiation levels are measured using sensitive thermoluminescent dosimeters continuously posted at locations outside of the boundaries of areas where radiological work is performed. Dosimeters are also posted at locations away from radiological work areas to measure background radiation levels from natural radioactivity. The results show that NNPP activities have had no distinguishable effect on normal background radiation levels at the perimeter of the work sites.

5.4.4.4 Independent Agency Monitoring

Environmental samples from each harbor monitored are also independently checked at least annually by a DOE laboratory to ensure that analytical procedures are correct and standardized. Additionally, the USEPA has conducted independent surveys in U.S. harbors, including areas on both the east and west coast (USEPA 1998b, USEPA 1999d, USEPA 2001a, USEPA 2001b, USEPA 2003b, USEPA 2004, USEPA 2005a, USEPA 2005b). The results are consistent with Navy monitoring results cited in NNPP 2007a. These surveys have confirmed that Naval nuclear-powered ships and their support facilities have had no adverse impact on the radioactivity of the marine or terrestrial environment.

5.4.4.5 Results of Environmental Monitoring

The Navy issues an annual report that describes the Navy's policies and practices regarding such issues as disposal of radioactive liquid, transportation and disposal of radioactive materials and solid wastes, and monitoring of the environment to determine the effect of nuclear-powered warship operations (NNPP 2007a). This report is provided to Congress and to cognizant federal, state, and local officials in areas frequented by nuclear-powered ships. This report shows that the total amount of long-lived gamma radioactivity released into harbors and seas within 12 miles of shore has been less than 0.002 curies during each of the last 36 years.

NRC regulation (10 CFR 20) lists water concentration limits for discharge of radioactivity in effluents. These limits are based on limiting the dose to members of the public from continuous ingestion of the

activity discharged to 50 millirem per year. The control of radioactive liquid discharges at Navy facilities is much more stringent than at facilities that comply with the limits of 10 CFR 20, such as commercial nuclear power plants. The total combined radioactivity discharged from all Navy nuclear-powered vessels annually within 12 miles of shore is less than one hundredth of the amount of radioactivity released by one typical commercial nuclear power plant. To put this small quantity of radioactivity into perspective, it is less than the quantity of naturally occurring radioactivity in the volume of harbor salt water occupied by a single Naval nuclear-powered submarine.

As a measure of the significance of this data, if one person were able to drink the entire amount of radioactivity discharged into any harbor in any of the last 36 years by U.S. nuclear-powered warships and support facilities, that person would not exceed the annual radiation exposure permitted for an individual worker by the NRC.

Since 1973, the total long-lived gamma radioactivity released farther than 12 miles from shore by Naval nuclear-powered ships and supporting tenders has been less than or equal to 0.4 curie per year. This is the total amount released from over 100 ships at different times of the year in the open sea at long distances from land in small incremental amounts, and under rapid dispersal conditions due to wave action. This 0.4 curie is less than the naturally occurring radioactivity in a cube of seawater approximately 100 yards on a side.

This data can be extrapolated to a CVN. The procedures used to operate and service a nuclear-powered CVN are based on the same principles used to develop those for U.S. nuclear-powered ships at any time in the past or any place in the world. Thus, homeporting a CVN would have no significant radiological environmental effect, and no adverse impact on the health and safety of the public.

5.5 EMERGENCY PREPAREDNESS

Naval reactors are designed and operated in a manner that is protective of the crew, the public, and the environment. It is important to note that the crew lives in very close proximity to the reactor and is dependent on the energy generated by the reactor for air, water, heat, and propulsion. Thus, it is imperative to both the Navy and the crew that the reactor be well designed and safely operated. An equally important part of ensuring safety is developing, exercising, and evaluating the ability to respond to any emergency in the highly unlikely event one does occur.

Planning for emergencies is based on extensive Naval Nuclear Propulsion Program technical analysis, as well as recommendations and guidance provided by numerous agencies experienced in emergency planning,

including the Department of Homeland Security (Federal Emergency Management Agency), the Navy, the Department of Energy, the Nuclear Regulatory Commission, the Environmental Protection Agency, the National Council on Radiation Protection and Measurements, and the International Atomic Energy Agency. Naval Reactors is the Federal Coordinating Agency under the National Response Plan for radiological emergencies involving Naval Nuclear Propulsion Program facilities and transportation accidents involving radiological or nuclear material generated from Naval Nuclear Propulsion Program operations. As such, Naval Reactors could call upon the extensive resources of the federal emergency response network, if ever needed. Emergency planning for the public is based on the above guidance, as well as specific planning requirements of local civil authorities.

All Naval Nuclear Propulsion Program activities, both shipboard and ashore, have plans in place that define Naval Nuclear Propulsion Program responses to a wide range of emergency situations. These plans are regularly exercised to ensure that proficiency is maintained. These exercises consistently demonstrate that Naval Nuclear Propulsion Program personnel are well prepared to respond to emergencies regardless of location. Actions are taken to continually evaluate and improve emergency preparedness at all Naval Nuclear Propulsion Program activities.

If there ever were a radiological emergency, civil authorities would be promptly notified and kept fully informed of the situation. With the support of Naval Nuclear Propulsion Program personnel, local civil authorities would determine appropriate public actions, if any, and communicate this information via their normal emergency communication methods.

The Naval Nuclear Propulsion Program maintains close relationships with civil authorities to ensure communications and emergency response are coordinated, if ever needed. Successful exercises have been conducted with all States that host U. S. nuclear-powered warships and facilities, demonstrating the Navy's commitment to work as a team in response to emergency situations.

Due to the unique design and operating conditions of U.S. nuclear-powered ships, civil emergency response plans that are sufficient for protecting the public from industrial and natural events (for example, chemical spills or earthquakes) are also sufficient to protect the public in the highly unlikely event of an emergency onboard a nuclear-powered ship or at a Naval Nuclear Propulsion Program facility.

5.6 OVERVIEW OF RADIOLOGICAL IMPACT ANALYSES AND HEALTH EFFECTS

This chapter has discussed at length the history and philosophy of the NNPP to illustrate the absence of any notable radiological impact associated with homeporting CVNs. Discussion has centered on the

small amount of radioactive material that has been released during normal operations and the conservative nature of naval fuel design and facilities design that make the likelihood of accidents and their consequences extremely small. Nonetheless, the radiological impacts of normal operations and facility accidents on the environment and exposure to the general public were evaluated at NAVSTA Mayport. These evaluations were performed taking into account local meteorological data, population, water movements, and other factors that could influence severity of an accident using a computer-programmed pathways analysis. A detailed discussion of analysis methods is contained in Appendix H. Estimated environmental consequences, event probabilities, and risk for both normal operations and postulated accident scenarios related to the homeporting of CVNs are presented.

5.6.1 Potential for Release of Radioactive Material to the Environment

Normal operations and accidents at support facilities were evaluated to estimate the potential for releases of radioactive material. The results of these analyses are presented in terms of the health effects to facility workers and the public as predicted due to the hypothetical release of radioactive materials into the environment. Additional discussion on radiation exposure and risk is provided in Appendix G, which supports the position that these analyses are conservative. Effects on environmental factors are also presented, based on the amount of land that could be impacted due to postulated accidents. The detailed analyses of normal operations and accident conditions for radiological support facilities are presented in Appendix H. The radioactive material release source term for normal operations was conservatively estimated for the NIMITZ-class aircraft carrier based on procedures approved by the USEPA for compliance with 40 CFR 61.

Accidents were considered for inclusion in detailed analyses if they were expected to contribute substantially to risk (defined as the product of the probability of occurrence of the accident and the consequence of the accident). The following example serves to illustrate the calculation of risk. The lifetime risk of dying in a motor vehicle accident can be computed from the likelihood of an individual being in an automobile accident and the consequences or number of fatalities per accident. There were 6,181,000 motor vehicle accidents during 2004 in the U.S. resulting in about 42,636 deaths (National Highway Traffic Safety Administration 2006). Thus, the probability of a person being in an automobile accident is 6,181,000 accidents divided by approximately 300,000,000 persons in the U.S., or 0.02 per year. The number of fatalities per accident, 0.007 (42,636 deaths divided by 6,181,000 accidents), is less than 1 since many accidents do not cause fatalities. Multiplying the probability of the accident (0.02 per year) by the consequences of the accident (0.007 deaths per accident) by the number of years the person is exposed to the risk (77.5 years is considered to be an average lifetime as of 2003 (Hoyert *et. al.* 2006))

gives the risk for any individual being killed in an automobile accident. From this calculation, the overall risk of someone dying in a motor vehicle accident is about 1 chance in 92 over their lifetime. Further perspective on the calculation of risk can be found in section 1.5 of Appendix H.

Accidents were categorized into three types: Abnormal Events, Design Basis Accidents, or Beyond Design Basis Accidents. These categories are characterized by their probability of occurrence as described further in section 2.6 of Appendix H. Construction and industrial accidents are included in these categories. Two hypothetical accidents were analyzed using area specific data. The first scenario is a fire in a radiological support facility that spreads to radioactive material resulting in an airborne release of radioactivity. The second scenario is a spill into surrounding waters of radioactive liquid from a collection facility.

5.6.1.1 Normal Operation

This section summarizes the detailed pathways analyses performed in Appendix H to determine the radiological impact of normal operations based on one CVN added to NAVSTA Mayport by this EIS. A detailed discussion of how the analyses were performed is contained in Appendix H.

Table 5.6-1 presents the estimated risk of fatal cancer to the general population and individuals at NAVSTA Mayport due to radiological releases from normal operations. The normal incidence of cancer for a typical population has been included for comparison. Details for deriving data in Table 5.6-1 are described in Appendix H. The radiation exposure to the general public would be so small at NAVSTA Mayport that it would be indistinguishable from naturally occurring from normal operations background radiation. The results show that the additional annual individual risk of a latent fatal cancer (LFC) occurring in the general population within 50 miles of NAVSTA Mayport is very low, less than 1 chance in 3.3 billion.

Table 5.6-1 Radiological Health Effects from Normal Operations

<i>Location</i>	Total Radiation Exposure to Affected Population¹	Annual Risk of Single LFC in Entire Affected Population²	Population Estimate Within 50 Miles of NAVSTA Mayport³	Average Annual Risk of LFC to a Member of the General Population⁴	Individual Annual Risk of LFC for Maximally Exposed Off-Site Individual⁵	An Individual's Annual Risk of Dying from all Cancers⁶
NAVSTA Mayport	0.9 (9×10^{-1})	1 in 2,326 (4.3×10^{-4})	1,393,489	1 in 3.3 billion (3.1×10^{-10})	1 in 29 million (3.5×10^{-8})	1 in 360 (2.8×10^{-3})
<i>Notes</i>	<ol style="list-style-type: none"> Total exposure to general population within a 50-mile radius of the facility due to normal operation (person-rem). Annual risk of a single latent fatal cancer in entire affected population within a 50-mile radius of the facility from radiation exposure due to normal operation is calculated by multiplying the total radiation exposure to affected population (rem) by 0.0005 latent fatal cancers estimated to be caused by each rem (risk/rem; see Table H-3 in Appendix H). Estimated number of people within a 50-mile radius of the facility from census data in Table H-4 Average annual risk of latent fatal cancer for an average individual within a 50-mile radius of the facility from radiation exposure due to normal operation is calculated by dividing the total population cancer risk by the number of people within a 50-mile radius of the homeport location. Risk of cancer is noted in parentheses. The MOI is a theoretical individual living at the base boundary receiving maximum exposure, calculated by multiplying the total radiation exposure to the MOI (rem; see Table H-11 of Appendix H) by 0.0005 latent fatal cancers estimated to be caused by each rem (see Table H-3 in Appendix H) Annual risk of an individual dying from all sources of cancer. Risk of cancer is noted in parentheses. 					

5.6.1.2 Hypothetical Accidents

Accident Selection and Scope

Natural and human initiated accidents were considered but only those accidents expected to contribute substantially to risk (defined as the product of the probability of occurrence of the accident multiplied by the consequence of the accident) were included for detailed analysis. In addition, before an accident was considered for detailed analysis, radioactive material associated with the accident had to be in a dispersible form and there had to be a way to release and disperse the material.

Categories of accidents, which are described in Appendix H and include industrial and catastrophic accidents, are characterized by their probability of occurrence. The probability of an accident's occurrence contributed significantly to whether the accident was included for detailed analysis. Accidents with minimal consequences, such as small-volume releases, procedural violations, and other human errors, occur more frequently than accidents with severe consequences. Accidents with low probability of occurrence but more severe consequences, such as acts of terrorism, plane crashes, and natural disasters (like earthquakes or hurricane storm surge), are expected to result in risks that are bounded by the results of facility accidents that were evaluated in detail. The facility accidents found to have the highest risk

were a fire in a radiological support facility and a release of radiological liquid (spill) from a support facility. Both accidents are analyzed in detail in Appendix H.

Although the probability of occurrence is very small, a wide range of postulated reactor accidents has been analyzed and are discussed in Appendix I. Consistent with independent reviews by the NRC and ACRS, the analyses have shown that CVN reactors can be safely operated.

For facility accidents, the scope of radiological impact as related to the size of the area contaminated was determined. The spread of contamination was calculated using average meteorological conditions (note that 95 percent worst case meteorology was used when calculating exposure and risk to workers and the general population). For the fire accident scenario the contaminated area was confined to the boundaries of NAVSTA Mayport. For the spill accident, the footprint was not calculated due to the rapid dilution below detectable levels of radioactive material after entering surrounding waters. Any radiological impact on the contaminated area would be temporary while the area was isolated and remediation efforts were completed.

Summary of Accidents Selected for Detailed Analysis

Fire

The accident with the most risk is a fire in a radiological support facility that results in the airborne release of radioactivity. The amount of radioactivity released during this accident scenario was conservatively established at 1 curie of cobalt-60 and the associated proportional amounts of other radioactive elements expected. Note that this amount of activity is more than 500 times the annual amount released to harbors within the 12-mile coastal waters by the entire nuclear navy. This represents a conservative amount of radioactivity that might be released in a fire, as compared to the typical amount that might accumulate within a support facility due to normal operations. For the analysis, several conservative assumptions were used, as follows:

- The meteorological conditions are considered to be 95 percent worst case (with no credit given that the likelihood of these conditions is only 1 chance in 20).
- No evacuation of the public or cleanup of contaminated areas is assumed.

These assumptions are conservative since radioactive material storage facilities are specifically constructed to inhibit the spread of fire and have automatic sprinkler systems installed. Moreover,

emergency response measures include provisions for immediate response to any emergency, identification of the accident conditions, and communications with state and local authorities.

This section summarizes the detailed pathways analyses, performed in Appendix H, which determined the radiological impact of a fire at radiological support facilities. Table 5.6-2 presents the estimated risk of cancer to the general population and individuals due to radiological releases resulting from a fire at support facilities. The risks presented in this section result from extremely conservative assumptions and analyses. A fire is the highest risk, most severe hypothetical accident, but its risk is still considered low when compared to other risks. Latent cancer fatalities are not expected in the general public as a result of this hypothetical radiological fire. The average annual individual risk of latent fatal cancer to the general public living within a 50-mile radius of NAVSTA Mayport due to a fire is very low, less than one chance in 1 billion.

Table 5.6-2 Summary of Radiological Support Facility Fire Results

Location	Total Radiation Exposure to Affected Population from a Fire, Assuming Fire Occurs ¹	Annual Risk of Single LFC in Entire Affected Population from a Fire, Including Probability of Fire Occurring ²	Population Estimate Within 50 Miles of NAVSTA Mayport ³	Average Annual Risk of LFC to a Member of the General Population from a Fire, Including Probability of Fire Occurring ⁴	Individual Annual Risk of LFC for a Maximally Exposed Off-Site Individual from a Fire Including Probability of Fire Occurring ⁵	An Individual's Annual Risk of Dying from all Cancers ⁶
NAVSTA Mayport	540 person-rem	1 in 770 (1.3×10^{-3})	1,393,489	1 in 1 billion (9.6×10^{-10})	1 in 1 million (9.7×10^{-7})	1 in 360 (2.8×10^{-3})
Notes	<ol style="list-style-type: none"> 1. This is the total exposure to affected population within a 50-mile radius of the facility due to a fire (person-rem). 2. Annual risk of a single latent fatal cancer in the affected population within a 50-mile radius of the facility from radiation exposure due to a fire is calculated by multiplying the total radiation exposure to affected population (rem) by 0.0005 latent fatal cancers estimated to be caused by each rem (see Table H-3 in Appendix H) by a 1 in 200 (0.005) probability of a fire. 3. This is the estimated number of people within a 50-mile radius of the facility from census data in Table H-4 in Appendix H 4. Average annual risk of latent fatal cancer for an average individual within a 50-mile radius of the facility from radiation exposure due to a fire is calculated by dividing the affected population cancer risk by the number of people within a 50- mile radius of the home port location. Risk of cancer is noted in parentheses. 5. The MOI is a theoretical individual living at the base boundary receiving maximum exposure. Risk is calculated by multiplying the total radiation exposure to the MOI (rem, see Table H-11 of Appendix H) by 0.0005 latent fatal cancers estimated to be caused by each rem (see Table H-3 in Appendix H) by a 1 in 200 (0.005) probability of a spill. 6. This is the annual risk of an individual dying from all sources of cancer. Risk of cancer is noted in parentheses. 					

Spill

The next accident with the most risk is a spill of radioactive liquid from a collection facility into surrounding waters. The released radioactivity is evaluated for transfer from the location of release to the general public through tidal movements, ingestion by fish and crustaceans. The amount of water release was assumed to contain 1 curie of cobalt-60 and the associated proportioned amounts of other radioactive elements expected. These assumptions are conservative since it would require a spill of over 26 million gallons of radioactive liquid (discharged primary coolant) at levels normally contained in collection facilities. The total capacity to store radioactive liquid at support facilities typically would be less than 100,000 gallons.

This section summarizes the detailed pathways analyses performed in Appendix H, which determined the radiological impact of a release of radiological liquid from support facilities. Table 5.6-3 presents the estimated risk of cancer to the general population and individuals due to radiological releases resulting from a release of radiological liquid from a support facility. The risks presented in this section result from extremely conservative assumptions and analyses. The risk from a spill is less than a fire and is also considered low when compared to other risks. Latent cancer fatalities are not expected in the general public. The average annual individual risk of latent fatal cancer to the general public living within a 50-mile radius of NAVSTA Mayport is very low, less than 1 chance in 120 billion.

5.6.1.3 Accident Response

Although the risk of a radiological accident of significant consequence is small, emergency plans are in place at all Naval nuclear facilities to mitigate the impacts of an accident. These plans include activation of emergency control organizations throughout the NNPP to provide on-scene response as well as support for the on-scene response team. Realistic training exercises are conducted periodically to ensure that the response organizations maintain a high level of readiness and to ensure that coordination and communication lines with local authorities and other federal and state agencies are effective. Emergency response measures include provisions for immediate response to any emergency at any naval site, identification of the accident conditions, and communication with civil authorities providing radiological data and recommendations for any appropriate protective action. In the event of an accident involving radioactive or mixed-waste materials, workers in the vicinity of the accident would promptly seek shelter to minimize exposure and aid in emergency response consistent with the site's emergency plan for responding to fires and hazardous material incidents. This typically occurs within minutes of the accident and reduces the hazard to workers.

Table 5.6-3 Summary of Radiological Support Facility Release of Radioactive Liquid Results

Location	Total Radiation Exposure to Affected Population from a Spill, Assuming Spill Occurs ¹	Annual Risk of Single Latent Fatal Cancer in Entire Affected Population from a Spill, Including Probability of Spill Occurring ²	Population Estimate Within 50 Miles of NAVSTA Mayport ³	Average Annual Risk of Latent Fatal Cancer to a Member of the General Population from a Spill, Including Probability of Spill Occurring ⁴	Individual Annual Risk of Latent Fatal Cancer for Maximally Exposed Off-Site Individual from a Spill, Including Probability of Spill Occurring ⁵	An Individual's Annual Risk of Dying from all Cancers ⁶
NAVSTA Mayport	240 person -rem	1 in 84,000 (1.2 x 10 ⁻⁵)	1,393,489	1 in 120 billion (8.6 x 10 ⁻¹²)	1 in 6 billion (1.7 x 10 ⁻¹⁰)	1 in 360 (2.8 x 10 ⁻³)
<p><i>Notes</i></p> <ol style="list-style-type: none"> 1. This is the total exposure to general population within a 50-mile radius of the facility due to a spill (person-rem). 2. Annual risk of a single latent fatal cancer in affected population within a 50-mile radius of the facility from radiation exposure due to a spill is calculated by multiplying the total radiation exposure to affected population (rem) by 0.0005 latent fatal cancers estimated to be caused by each rem (risk/rem; see Table H-3 in Appendix H) by a 1 in 10,000 (0.0001) probability of a spill. 3. This is the estimated number of people within a 50-mile radius of the facility from census data in Table H-4 in Appendix H 4. Average annual risk of latent fatal cancer for an average individual within a 50-mile radius of the facility from radiation exposure due to a spill is calculated by dividing the total population cancer risk by the number of people within a 50- mile radius of the home port location. Risk of cancer is noted in parentheses. 5. The MOI is a theoretical individual living at the base boundary receiving maximum exposure. Risk is calculated by multiplying the total radiation exposure to the MOI (rem; see Table H-11 of Appendix H) by 0.0005 latent fatal cancers estimated to be caused by each rem (risk/rem; see Table H-3 in Appendix H) by a 1 in 10,000 (0.0001) probability of a spill. 6. This is the annual risk of an individual dying from all sources of cancer. Risk of cancer is noted in parentheses. 						

While the Navy would recommend appropriate actions to protect the public if needed based on Federal guidance (EPA 400-R-92-001), State and local officials would be responsible for determining and implementing protective actions for the general public outside of the Naval base. In the highly unlikely event that some radioactivity escapes from the Naval base, the radioactivity would still only affect areas close to the release, and the exposure to the public would be localized and not severe. As such the need for the State and local officials to take protective actions is extremely low. However, in the highly unlikely event that some action were necessary, existing civil emergency response plans in place for handling industrial and natural events (for example, chemical spills or hurricanes) are more than sufficient to protect the public in response to a radiological emergency originating from the Naval base.

5.6.2 Impact on Specific Populations

5.6.2.1 Impact on Workers

The impact to workers involved in radiological support facility operations due to the postulated radiological accidents has been evaluated. This evaluation focused on the radiological consequences of the fire accident. Clearly, a limited number of fatalities may occur that are related to operations and support only in a secondary manner; i.e., the worker who happened to be in the facility may be killed due to a fire. These secondary effects are not discussed in the evaluation. Rather, only radiological consequences are considered. It is not likely that any adverse impact to the health of nearby workers would occur due to the radiological consequences of this fire accident. At most, a few workers might receive some radiation exposure from inhalation of airborne radioactivity during the initial stages of the fire; however, the involved workers would likely move to a position upwind of the fire, put on breathing apparatus, or evacuate the area in accordance with emergency procedures and training.

For the spill accident, the water would drain from the tank and rapidly enter the water pathway. In addition, wet spills result in very small amounts of airborne activity. It is not likely that any adverse impact to the health of nearby workers would occur due to radiological consequences of this spill accident.

5.6.2.2 Impact on Environmental Justice in Minority and Low Income Populations

As discussed in the preceding sections, the impacts on human health or the environment resulting from normal operations associated with support facility operations for CVNs would be small. For example, it is unlikely that a single additional fatal cancer would occur as a result of these activities. Since the potential impacts due to normal operations or accident conditions present no significant risk and do not constitute a credible adverse impact on the surrounding population, no adverse effects would be expected for any particular segment of the population, minorities and low-income groups included.

The conclusion that there would be no disproportionately high and adverse impacts on human health or the environment is not affected by the prevailing winds or direction of surface and subsurface water flow. This is true for normal operations because the effects of routine operations are so small. It is also true for accident conditions because the consequences of any accident would depend on the conditions at the time it occurred and the wind directions do not display any strongly dominant directions. Similarly, the conclusion is not affected by concerns related to subsistence consumption of fish and game since the sites are not located in areas that serve as a major source of food for any specific group.

To place the impacts on environmental justice in perspective, the risk would be less than one additional fatality per year for the entire population from CVN support operations. Even if all of the additional impacts were assumed to occur solely among minorities and low income populations, no additional latent cancer fatalities are expected to occur in the population from carrier support operations. Thus, the cancer risk would not constitute disproportionately high and adverse impacts on human health or the environment.

5.7 SUMMARY

The NNPP provides comprehensive technical management of all aspects of Naval nuclear propulsion plant design, construction, and operation including careful consideration of reactor safety, radiological, environmental and emergency planning concerns. The record of the NNPP's environmental and radiological performance at the operating bases and shipyards presently used by nuclear-powered warships demonstrates the continued effectiveness of this management philosophy. This effectiveness is demonstrated by the fact that through the entire history of the Program – over 5,900 reactor years of operation and more than 137 million miles steamed on nuclear power – there has never been a reactor accident, nor any release of radioactivity that has had an adverse effect on human health or the quality of the environment.

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