Department of Homeland Security (DHS):

DHS health and safety report on Non-Intrusive Imaging (NII) container scanning technology

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Homeland Security

1.0 Introduction

A primary mission of the Department of Homeland Security (DHS), through the Domestic Nuclear Detection Office (DNDO), is to protect the United States by enhancing and coordinating the efforts of Federal, State, local, and tribal governments to detect the unauthorized importation, possession, storage, transportation, development, or use of a nuclear explosive device, fissile material, or illicit radiological material. These efforts involve cooperation between U.S. Customs and Border Protection (CBP), charged with preventing the entry of terrorists and their weapons, and the Departments of Defense, Justice, State, and Energy, and the Nuclear Regulatory Commission which have roles in establishing international radiation detection and protection programs and agreements.

Both DNDO and CBP are developing or using Non-Intrusive Imaging (NII) technology to protect the Nation by ensuring that our borders are secure from potentially dangerous cargo or individuals entering the country. NII systems, in many cases, give CBP officers the capability to perform thorough examinations of cargo without having to resort to the costly, time consuming process of unloading cargo for manual searches, or intrusive examinations of conveyances by methods such as drilling and dismantling. However, these NII systems have potential environmental health and safety impacts that must be addressed to ensure that any radiation exposure of workers or the public are maintained at levels that are as low as reasonably achievable and below U.S. and international limits.

In the *Security and Accountability For Every Port Act of 2006 (PL 109-347)*, the Congress directs DHS to address the following:

> Sec 121 (b) (6) an evaluation of the environmental health and safety impacts of Non-Intrusive Imaging (NII) technology and a radiation risk reduction plan, in consultation with the Nuclear Regulatory Commission, the Occupational Safety and Health Administration, and the National Institute for Occupational Safety and Health, that seeks to minimize radiation exposure of workers and the public to levels as low as reasonably achievable;
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> Sec 121 (d) Not later than 180 days after the enactment of this Act, the Secretary may update the strategy submitted under subsection (c) to provide a more complete evaluation under subsection (b) (6).

DHS addressed section 121 (b)(6) in its report titled “Report To Congress: Strategy For The Deployment Of Radiation Detection Capabilities”, dated January 18, 2007.

This DHS report provides a more complete evaluation of section 121 (b)(6) as requested by section 121 (d).

2.0 Currently Deployed NII Systems and NII Systems to Be Deployed by CBP

Background:

CBP has utilized a growing number of NII systems since 1996. These systems have a single gamma source, an x-ray tube, or an accelerator. A single neutron generating system was tested from 2004 to 2006, but has since been decommissioned.

Prior to 2000, radiation exposure was controlled either by containment in cabinet type x-ray systems or by establishment of a large radiation controlled zone for gamma scanning systems. CBP formalized radiation limits for employees in 1997 as new models of gamma systems and the first large x-ray and accelerator systems were procured. These limits were established to ensure that CBP employees (and others) were always within radiation dose limits of the 'general public' (100 millirem in a year) rather than those of the 'radiation worker' limit (2,000 millirem in any year, and not more than 5,000 millirem in any one year during a 5 year period) (see International Council on Radiation Protection ICRP Supporting Guidance 4). It is worth noting that International Radiation Allowances have been reduced for radiation workers, but not the general public. CBP has always participated in the design and fielding of systems in order to ensure that maximum exposures for current generation systems are at or below U.S. and international limits for the general public. In order to meet these requirements, CBP has developed system measurement requirements to ensure that distances needed to establish a controlled zone are defined for each system.

Radiation safety requirements in the U.S. are under the jurisdiction of multiple Federal agencies. These requirements are not standardized, and even basic terminology is inconsistent. CBP worked with several groups, such as the Interagency Steering Committee on Radiation Standards, and the American National Standards Institute (ANSI) committee N43.16, to harmonize radiation safety requirements. A final draft of N43.16 standard on radiation safety for NII systems is expected before the end of 2007. CBP also works closely with the National Institute for Occupational Safety and Health (NIOSH) and the Occupational Safety and Health Administration (OSHA) to work on appropriate revisions of the OSHA radiation safety regulations.

System Measurements:

Historically, CBP developed radiation controlled zones for radiation systems (gamma, x-ray, and accelerator) as established in the NRC requirements for gamma systems to protect workers that are not occupationally exposed. This was required for personnel who are likely to be working within or near the systems as either primary operators or secondary operators (ground personnel). All historical and current systems do not scan drivers.

Gamma and x-ray system controlled zones are based on remaining below 50 microrem in any hour (without subtracting for background radiation) (10 CFR 20.1301 requires dose

to be below 2000 microrem in any hour). With 2,000 hours in a work year, if employees stay below 50 microrem in any hour, they will always remain below 100 millirem (or 100,000 microrem) a year. NIOSH has estimated that the annual dose to a truck driver that transports cargo (sealand container) through a stationary gamma-ray screening system is likely to be no higher than 15 to 18 millirem in a year (10 CFR 20.1301(a)(1) requires dose to be below 100 millirem in a year). This assumes the driver works 365 days per year (which overestimates the driver's actual dose). During actual operation of the screening system, the driver is not exposed to an active beam. This is also the standard operating procedure for the scanning systems used in international ports as part of the Secure Freight Initiative (SFI). In the SFI ports, sensors activate the beam only after the front portion of the truck drives through the system to ensure that the drivers remain unexposed.

Many new systems have been explored in the development of the next generation of systems to address the need to scan more cargo, penetrate denser items, and meet the full mission of DHS. Advances in collimation of energy beams, the use of pulsing technology, and refinements in analysis have made it possible to work near higher powered machines while establishing the smallest possible radiation control zones. In the next generation of systems, active scanning with drivers remaining in vehicles is being considered. In part, this is due to publications in the U.S. (National Council for Radiation Protection Report No. 116 - *Limitation of Exposure to Ionizing Radiation* (Supersedes NCRP Report No. 91)) and internationally (International Council for Radiation Protection (ICRP) Publications 54 and 78) which conclude that an annual effective dose per source or practice of less than 1 millirem is a 'negligible individual dose'.

Modeling, in coordination with NIOSH, will also be performed to determine how often an individual driver might pass through a system in a single day or year to estimate a maximum potential exposure. This modeling will be completed by the end of 2007. Early estimates place the cumulative exposure in any year as well within the Public Allowance. This is based on observations of drivers at seaports and delivery drivers crossing the U.S. land borders; where it appears probable that no one operator would be scanned more than twice in any hour at a seaport, and less than 4 times in a day at any land crossing. Extrapolating, if a driver were to pass through a system 10 times in a day, 365 days a year and received 10 microrem per inspection, his exposure at the end of the year would be 36 millirem – well within the U.S. and international allowance of 100 millirem in any year (above background). Similarly, the cumulative exposure at the same rate of scanning (365 days a year at 10 times every day) at 4 microrem per inspection would result in 14.2 millirem in any year.

Environmental Compliance:

Compliance with environmental laws and regulations has always been an integral component of the CBP NII program. CBP NII program managers are members of Integrated Process Teams tasked to ensure that NII programs comply with Federal environmental laws and regulations. Programmatic Environmental Assessments are developed for all major programs defining the "general" expected impacts associated

with the program. As individual systems are procured and fielded, "site specific" environmental assessments are developed detailing the more specific (local) impacts that may reasonably be expected to occur, along with any mitigation strategies intended to minimize those effects. All gamma systems utilize sources that are periodically checked as required to insure that no radioactive material has leaked . The current x-ray accelerator systems do not release or produce radioactive material. This requirement will be considered when evaluating new systems. In this manner, CBP ensures that employees, the general public, and the natural environment are protected from any harmful effects of using NII equipment.

CBP has developed the following classes of environmental documents:

- Programmatic Environmental Assessment for Gamma Imaging Systems
- Site-specific environmental assessments for Gamma Imaging Systems
- Site-specific environmental assessments for High-Energy Mobile X-Ray Inspections Systems
- Site-specific environmental assessments for Radiation Portal Monitors
- Site-specific environmental assessment for Fast Pulsed Neutron Analysis System

CBP is currently developing Programmatic Environmental Assessments for:

- High-Energy NII Systems End of CY 07
- Mid-Energy NII Systems End of FY 08
- Low-Energy NII Systems End of FY 08

3.0 NII Systems in development by DNDO

Background:

DNDO has been charged with developing new systems for cargo screening to detect nuclear materials or threats smuggled into the U.S. The Cargo Advanced Automated Radiography System (CAARS) is an NII developmental system that will have the capability to automatically detect material containing elements with high atomic numbers (high Z) in addition to conventional radiographic imaging capability. Elements with high Z (>72) include fissionable Special Nuclear Materials (SNM) and other elements that would be highly effective in shielding SNM or other radioactive materials from passive detection. CAARS is a photon based system that will be able to detect ranges of high Z to detect SNM. Photon based systems do not have the ability to identify specific isotopes. CAARS will also possess conventional radiographic imaging capability to detect drugs, high explosives, and other contraband in cargo containers.

CAARS is currently eight months into a 24 month development program which will be followed by nine months of intensive testing. Upon completion of testing, a production decision will be made resulting in Low Rate Initial Production (LRIP) units being deployed in FY 2010.

CAARS is an active scanning system using high-energy x-rays to image vehicles and cargo containers/conveyances. The initial design will not include neutron sources, gamma-ray spectrometers, or neutron detectors for active interrogation.

Energy levels up to 10 MeV will be used for CAARS. Systems with energy levels greater than 6 MeV have the potential to generate neutrons. Modeling, engineering studies, and testing will be conducted to ensure that proper shielding is incorporated to address concerns associated with neutrons. CBP is currently looking at procuring systems with energy levels greater than 6 MeV. Lessons learned from the 6 MeV systems and CAARS will be shared amongst each other.

The CAARS high-energy x-ray sources may pose a health risk to personnel. Thus, in order to avoid exposing personnel to potentially harmful levels of radiation, the beams generated from the CAARS x-ray sources must be properly shielded so as to not expose personnel operating the system or located near the vehicle or containers/conveyances being inspected. It is expected that personnel will be removed from the vehicle before inspection.

CAARS is being developed to meet the same standards of radiation protection for operators and the general public as CBP applies to their current systems. The CAARS development specification uses the same definitions and values for radiation levels to the public that are utilized by CBP. The same methodology currently in place at CBP to define a controlled zone will be applied to CAARS when they are fielded. The following are required elements of CAARS: no more than the public level of exposure (100 millirem) in any year for operators or others near the system; absolute control of the system both automatically and by DHS employees such that if a vehicle stops within the scan beam, the radar and sensor interlocks will end the scan within a second; and exposures will always be well below 10 microrem in any scan. Studies are being performed to ensure that the developed products will meet these standards and elements.

The CAARS program team has recognized that there are many issues that must be addressed concerning health and environmental issues. The CAARS team will be completing the following efforts in order to address these issues:

- Review of CAARS by the National Council for Radiation Protection (NCRP)
- Health physics study (modeling and benchmarking)
- Health and environmental studies
- Systems testing
- Review of NII health and environmental issues by working group

National Council for Radiation Protection (NCRP)

Several technical questions have arisen regarding inadvertent exposure to radiation from CAARS. DNDO is seeking expert advice in the area of radiation protection from the NCRP, a non-profit organization chartered for this purpose by the U.S. Congress in 1964.

The NCRP draws on a large group of national experts on radiation health physics, which can be called upon to offer specific guidance on the possible effects identified above. A committee has been convened comprising experts from academia, National Laboratories, the National Institute of Standards and Technology (NIST), and the NCRP staff.

The areas of concern that NCRP is addressing are:

1. The dose and potential health effects of inadvertent exposure of a person by the CAARS radiography system

    - What would be the possible range of absorbed doses received by an individual exposed to CAARS x-rays in a typical cargo container/conveyance?
    - What is the maximum permissible exposure of such an individual, taking into account the national security goals of using CAARS to detect high-Z materials in cargos and the likely use of warning systems to give advance notice to an individual who might be exposed?
    - What types of warning systems should be installed in the pre-screening and operational control areas to minimize the probability of such an inadvertent exposure incident?

2. Effective and reliable methods of measuring exposure rates for high-energy CAARS x-rays using survey meters. Currently available survey meters typically are calibrated at energies only up to ~ 2 MeV, whereas CAARS will be using energy levels up to 10 MeV.

    Radiation measurement and dosimetry issues to be addressed include:

    - Can dose rates for high-energy x rays be accurately measured using conventional survey meters?
    - What equipment is available for this purpose, and what calibration procedures should be used to insure that measured dose rates are accurate?
    - When using an ion-chamber survey meter, such as the Fluke 451P, what procedures should be used to make dose measurements in the beam and out of the beam (scatter field)?
    - What accuracy can be expected from such measurements and on what technical basis?

DNDO is providing the NCRP with technical information that documents the operational characteristics being designed into CAARS, including the energy spectrum, pulse characteristics, dose rates for x-ray beams to be used, and the extensive set of calculations and measurements that have been performed on CAARS model systems to date.

NCRP will complete its initial report on CAARS in summer 2007, with its final report being available in December 2007. Issues addressed by NCRP will be incorporated into the CAARS prototypes which are scheduled for testing in FY 2009.

Health Physics Study (Modeling and Benchmarking)

The purpose of the Health Physics Study (HPS) is to provide an evaluation of the health and safety impacts of the CAARS technology on the public, operators, and inadvertent occupants (stowaways) and to produce a radiation risk reduction plan. To assess the radiation dose in and around the CAARS unit, the HPS team is employing calculations and models as well as physical testing to ensure modeling results are consistent with actual exposure levels. During testing, physical measurements will be performed to confirm that CAARS is operating safely.

The overarching strategy employed in the HPS is to: develop a generic CAARS configuration which meets the Performance Specification; develop a worst case radiation exposure scenario necessary to accomplish the CAARS mission; identify a reasonable worst case set of cargos; perform calculations of increasing complexity and realism starting with rough order of magnitude (ROM) hand calculations, followed by deterministic modeling and then Monte Carlo modeling; conduct experiments to verify modeling results; and examine vendor-specific designs to assess health physics issues and provide recommendations.

Initial modeling and benchmarking has been completed on a generic CAARS system-consisting of a dual energy x-ray system using a 6 and 9 MeV radiation source. The results of this generic system modeling indicate that areas external to the CAARS unit can be adequately shielded to ensure the public dose rate is less than 50 microrem/hr and the dose to an inadvertent occupant in a single scan will be less than the recommended limit for annual dose to a non-radiation worker (100 millirem). To check the degree of agreement between these modeling results and measured exposure levels, the HPS Team conducted a set of measurements employing the Lawrence Livermore National Laboratory (LLNL) L3000 9 MeV x-ray source, irradiating several targets and obtaining measurements which were subsequently compared to model predictions. This modeling and benchmarking effort will incorporate the vendor-specific designs as they become available and will continue through development and testing.

As the vendor configurations are defined, both the vendors and the HPS Team, including NCRP are examining the health physics issues associated with each vendor's design to ensure that the public, operators, and inadvertent occupants will not be exposed to levels exceeding general public standards. Subsequent updates to the HPS Report will include a level of analysis comparable to the generic configuration for each vendor design, followed by actual field measurements conducted on the prototype during System Qualification Tests, Development Test & Evaluation, and Low Rate Initial Production (LRIP) for successful vendors.

At this stage of development, no issues have surfaced that indicate that the vendor designs will not meet the CBP and CAARS Specification requirements. Agreement between models and measurements provide confidence that the modeling methods applied to the problem adequately account for the underlying physical scenario.

Health and Environmental Studies

The following Contractors will be developing prototype systems for the CAARS program:

- L3 Communications/Bio-Imaging Research (BIR)/Varian Team
- American Science and Engineering (AS&E)/Passport Team
- Science Applications International Corporation (SAIC)

During the development phase these contractors will perform studies and produce the following reports associated with health and environmental issues:

- System Safety Program Plan
- Environmental Impact and Personnel Health Hazard Assessment Report
- Hazardous Material and Management Report

Testing

The CAARS program has a very rigorous test program that will be addressing health and environmental issues throughout the life cycle of CAARS. The CAARS testing will be comprised of the following test events:

- Vendor development testing (VDT)
- System Qualification Test Readiness Test (SQTRT)
- System Qualification Test (SQT)
- Development Test and Evaluation (DT&E)
- Operational Test and Evaluation (OT&E)
- Spiral Development Testing (SDT)

The results from each test event regarding health and environmental issues will be incorporated into the system designs.

Working Group

A working group has been established to address health and environmental issues associated with CAARS. The initial kickoff meeting for this working group was held January 11, 2007. The nineteen attendees included representatives from DHS (CBP NII program manager, DNDO CAARS program managers, CBP Radiation Safety Officer, and CBP Environmental Staff) representatives OSHA, NIOSH, NIST, Food and Drug Administration (FDA), Nuclear Regulatory Commission (NRC), Pacific Northwest National Laboratory (PNNL), and supporting contractors. This group will continue to meet on a semi-annually basis with more frequent meetings as required. Any issues that are identified for CAARS and that are applicable for the currently deployed CBP systems, or systems under development for CBP, will be applied to those systems as well.

In the future this working group will involve the public sector to get the health and environmental issues associated with NII circulated in the public sector as required prior to publication and prior to actual fielding or even testing in commerce. CBP outreach to business, labor, and the public will be the model used for the CAARS roll out.

Since the initial kick off meeting this working group has completed the following activities:

- Two new accelerator systems were tested on January 30-31, 2007, at Long Beach, CA to finalize testing for future CAARS type systems.

- PNNL and CBP surveyed an accelerator system at Seattle, including radiation dose to cargo on February 13-14, 2007 to further validate the testing methodology.

- On March 7-8, 2007, members of the ANSI N43.16 committee representing NIST, OSHA, CBP and the U.S. Army, as well as a NIOSH scientist not on the committee, tested current CBP gamma and large x-ray systems and one model of the future CAARS system to finalize best testing methods for incorporation into the ANSI N43.16 safety standard. Global positioning data were captured on this test as well to verify the controlled zone.

- A draft Environmental Assessment for a High-Energy Fixed X-Ray Inspection System is currently under development. The High-Energy Fixed X-Ray Inspection System will be used to detect concealed contraband in suspected vehicles using a 6 MeV x-ray accelerator. The system can inspect different size vehicles (tractor-trailers to passenger cars) with cargo loads ranging from full to empty. The x-ray system is enclosed in a facility large enough to allow the passage of the largest commercial vehicles using public roadways. CBP intends to apply the format and analysis protocols used in the development of this environmental assessment to the CAARS Programmatic Environmental Assessment.

4.0 Conclusion

DHS, including Customs and Border Protection (CBP) and DNDO, fully understands the environmental health and safety impacts of NII technology. DHS has a comprehensive radiation risk reduction plan, and will continue to work closely with the NRC, OSHA, and NIOSH to minimize radiation exposure of workers and the public to levels as low as reasonably achievable. DHS will continue to monitor environmental health and safety impacts associated with NII technology by constantly addressing these impacts with systems currently deployed and systems under development.

As CAARS is developed, DHS will constantly be addressing environmental health and safety issues. These issues will be addressed by NCRP, modeling and benchmarking

conducted by the HPS team, health and environmental studies, extensive testing, and the health and environmental working group. All the results from these efforts will be applied to CAARS and all of the NII systems currently deployed by CBP to ensure that radiation exposure of workers and the public is minimized and maintained at levels as low as reasonably achievable.