THE DETECTION AND RECOVERY OF CONTRABAND
NUCLEAR MATERIAL

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I. Introduction

The theft of a nuclear weapon or of material capable of being fashioned into an explosive device could have cataclysmic consequences for the American public. Therefore, the various federal agencies responsible for the security of nuclear weapons and materials have gone to great lengths to forestall a successful theft. However unlikely, though, such an occurrence remains possible.

The consequences of such an event may not be completely technical in nature and, in fact, the largest impact may be in non-technical or "societal" areas. It had been widely assumed before the incident at Three Mile Island (TMI) that the consequences of a nuclear accident would be limited to immediate deaths, somatic diseases, economic loss, and general destruction.¹ The TMI incident showed that assumption to be patently false. Although there has been a good deal of controversy about the extent of the incident's technical consequences,² it is clear that the societal consequences were vast and far-reaching. On an individual level, personal fear and stress, economic loss, mistrust of authority, and loss of productivity certainly resulted. Media confusion, alarmism, and civil disorder were collective societal consequences. Institutional reactions included the reorganization of the Nuclear Regulatory Commission, cessation of power plant licensing proceedings, jurisdictional confusion, and a variety of special investigations.³ The nation was clearly unprepared for consequences of these dimensions.

In an effort to reduce our dependence on foreign oil, the present administration is committed to the exploitation of nuclear energy,⁴ although specifics of advanced nuclear energy systems have not been discussed in

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² See, e.g., N.Y. Times, Apr. 22, 1979, § 1, at 25, col. 5, 6; id., Apr. 8, 1979, § 1, at 28, col. 2, 4.


much detail. Several nuclear energy options, including the two most likely - fast breeder reactors and recycling of plutonium - involve the use of material capable of being fabricated into an explosive. This material will be in the private sector, albeit licensed and heavily regulated, and controlled by a safeguards system of nuclear material accounting and physical security.

Nuclear material accounting involves systematic sampling and analysis to verify that material supposed to be present is, in fact, in the possession of the licensee. Physical security includes the use of barriers, sophisticated surveillance techniques, and armed guard forces. Accounting serves to detect theft by providing a "timely" indication that material is missing and security provides a deterrent by creating multiple obstacles to a theft attempt. The major emphasis of safeguards planning and policy making has been on detection and deterrence, rather than on post-event strategy.

Nuclear activities in the United States fall basically into three categories. One is nuclear weapons production, largely unknown to the public because of the secrecy surrounding defense activities. There are also two publicly regulated uses for nuclear materials - medical applications and energy production. Nuclear medicine involves the use of short-lived radioactive materials primarily as tracers in radiographic analysis. Nuclear materials used in medical applications are, for the most part, not a significant threat to the general public. However, nuclear energy production involves the use of materials which can present a serious threat to public safety without the shield of secrecy surrounding the weapons production program.

Nuclear energy is a matter of serious debate around the world. Currently the production of electricity from nuclear materials is dominated by the use of light-water-reactors (LWR) and low-enriched uranium (LEU) fuel. LEU fuel cannot be used to make a nuclear explosive and its level of radioactivity is extremely small. However, once LEU fuel is "burned" in an LWR a portion of the uranium in the fuel is turned into plutonium. United States utilities keep burned, or "spent" fuel in temporary storage. Spent fuel is lethally radioactive. If plutonium is recovered from spent fuel by remotely controlled chemical reprocessing it can be recycled as reactor fuel. It can also be used to make a nuclear explosive. The chemical reprocessing concept is exactly the same for both energy fuel recycling and weapons production. Only the end use of the plutonium is different.

The present administration has also called for the development of a commercial fast-breeder-reactor (FBR). An FBR can be designed and

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5 See, e.g., Questions Abound for French Nuclear Program with Mitterrand's Election, NUCLEONICS WEEK, May 14, 1981, at 1; Derailed German Nuclear Program Inches Buck Toward the Track, id., March 26, 1981, at 1.

operated to produce more fuel than it uses. This anomalous condition actually results from putting a useless form of uranium into the reactor. The nuclear reaction inside the reactor turns it into plutonium. An FBR is designed to convert more uranium to plutonium than the plutonium it burns up. This concept of using plutonium to produce electricity has been phrased the "plutonium economy."

Plutonium is a man-made element with a radioactive half-life of 24,600 years. If configured correctly, it can produce massive amounts of electricity or an explosion of multiple kiloton equivalents. It is highly poisonous and is thus a threat to any population center in which it is dispersed. Other advanced nuclear energy systems currently under consideration involve pure uranium-235, material used in at least one United States nuclear explosive, and uranium-223, also capable of producing an explosion. LEU fuel is almost entirely uranium-238, which cannot produce an explosion, but an LWR converts it to plutonium as it operates. Materials capable of being fashioned into an explosive are called "fissile" materials.

The purpose of this article is to explore one particular societal consequence which could result from a theft of plutonium, uranium-235, or uranium-233 from energy production facilities. The potential legal implications of a plutonium economy will affect both constitutional and administrative law.

At present virtually all plutonium in the commercial sector is contained in spent fuel at reactor sites and very little uranium-235 or -233 is currently at any energy facilities. The Reagan administration and Congress have signalled a favorable climate for advanced nuclear fuel systems which will employ fissile materials. The feasibility of detection and subsequent recovery of nuclear fissile material illicitly removed from a facility is a question which has rarely been addressed. This article will explore the adequacy of remote detection and location devices designed to find contraband fissile nuclear materials and will examine the legal consequences of going beyond remote detection and location to actual searches for contraband. The TMI incident made it clear that such societal consequences were not given sufficient attention in the past and their relevance to the issue of whether to use a plutonium economy is unquestionable.

II. THE CONCEPTS OF DETECTION

A. Looking for Nuclear Materials

All fissile nuclear material is radioactive and emits either gamma rays or neutrons or both. These radioactive emissions may provide a means of "observing" the presence of nuclear material with the aid of radiation detectors. The detectors contemplated in this article are designed for surveillance at controlled access points from an area containing fissile material
and for locating the material after it has been removed from the area in an unauthorized fashion.

The specific types of fissile materials which are important in the nuclear fuel cycle from a security standpoint are plutonium (Pu), uranium-233 ($\text{U}^{233}$), and uranium-235 ($\text{U}^{235}$). These are the fissile materials which can be fashioned into nuclear fission explosive devices. All of these materials emit gamma and neutron radiation which can be observed by radiation detectors with varying efficiencies. A brief discussion of the technical characteristics of these materials will demonstrate the uncertainties involved.

A detector for fissile nuclear material is set up first to monitor the level of radiation which is normal to the area being searched. It must be recognized that gamma rays and neutrons are constantly passing through all terrestrial environments and that detection involves looking for “extra” sources of radiation. So a normal radiation measurement is made, and then samples of an area to be searched are compared to normal levels. When an area has significantly more radiation than it should, it is assumed that an extraneous source, for example, contraband nuclear material, is producing the excess.

Fissile nuclear material can be “shielded,” however, and made more difficult to detect by placing a sufficient quantity of material resistant to the passage of radiation around the it, thereby shielding it from detection. Typically, lead may be used. The thickness of lead sufficient to shield fissile materials from detection by blocking gamma radiation varies with the type of material being hidden. $\text{U}^{235}$ has the least energy associated with its gamma emissions and, as a result, a quarter inch of lead can reduce its detectability via gamma rays by a factor of 1000. Pu is not as easily shielded because of its higher-energy gamma emissions, but a one-inch thickness of lead can reduce its gamma emissions by a factor of 100 or more. In the case of $\text{U}^{238}$, it is very difficult to shield gamma radiation because all $\text{U}^{238}$ fuels also contain some $\text{U}^{232}$ which decays to produce thallium-208 ($\text{Tl}^{208}$) which, in turn, produces extremely high-energy, easily detectable gamma radiation.

An alternative to looking for gamma radiation is to look for neutron emissions. Both Pu and $\text{U}^{233}$ emit sufficient neutron radiation to be detectable with radiation detectors. It is possible to shield neutron emissions as well, but the best shielding material is “borated” plastic. Heavy metals, such as lead, do not interdict neutrons, while low-density materials such as plastics will slow down and capture most neutrons. Boron, an element

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7 $\text{U}^{233}$ is considered fissile material only when it is in a concentration greater than 20%. All references in this article to $\text{U}^{233}$ will be to uranium enriched to a 20% or greater concentration.

8 E. Weinstock, The Spiking of Special Nuclear Material as a Safeguards Measure, at II-1 (BNL-TSO File No. 5.9.1, Sept. 19, 1975) (prepared for the U.S. Nuclear Regulatory Comm’n).
which readily absorbs neutrons, will capture the remainder if mixed with a low-density medium like plastic and thus, borated plastic. This type of shielding must be very thick and bulky, however, to be at all effective.  

B. Spiking Fissile Materials

Spiking is the adding of other radioactive materials to fissile materials in order to enhance their detectability even through substantial shielding. The two types of spikants under consideration are gamma-emitting and neutron-emitting spikants. Each of these spikants will be examined briefly in order to define the limits of their utility.  

1. Gamma-Ray Spikants

Three radioactive substances suggested as gamma spikants are thorium-228 (Th$^{228}$), cobalt-60 (Co$^{60}$), and yttrium-88 (Y$^{88}$). Th$^{228}$ does not, in itself, increase gamma emissions when added to fissile materials but one of its daughter products, Tl$^{208}$, produces very powerful gamma radiation. However, several days must elapse after purification before enough Tl$^{208}$ is produced from Th$^{228}$ to be effectively detected. A disadvantage is that Th$^{228}$ decay produces harmful alpha radiation which may raise health-physics considerations among workers at nuclear facilities. While high levels of alpha radiation may be dangerous, they add little to a material's detectability.

Co$^{60}$ gamma radiation is somewhat less powerful than that produced by Th$^{228}$ decay, but its longer half-life is more convenient and it is more readily available than Th$^{228}$.

The gamma radiation emitted by Y$^{88}$ is more powerful than that by Co$^{60}$, but its half-life is very short by comparison and it is undetectable after about 100 days.

If U$^{232}$ were added to U$^{235}$ fuels, it would decay to produce Th$^{228}$. U$^{232}$ is virtually impossible to separate from U$^{235}$ so that it would constitute an unremovable "fingerprint." U$^{232}$, however, suffers the same disadvantage as Th$^{228}$. An even greater time must pass, on the order of weeks or months, for sufficient decay to produce enough Tl$^{208}$ to be reliably detected by radiation detectors. It should be noted that any aged U$^{233}$ materials will contain enough U$^{232}$ to be detected even through substantial shielding.

In the process stream, Th$^{228}$ may create problems because it is more toxic than the other candidate spikants. This toxicity is due to high alpha emission rates, but since it would add by only about a third to the existing

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9 Id. at II-21.
10 An added problem with spiking is its clear disregard for the As-Low-As-Reasonably-Achievable (ALARA) standard of minimizing employees' exposure to excessive radiation risks. Whether spiking would create an excessive risk is a policy question.
11 See INT'L RESEARCH AND TECHNOLOGY CORP., MODIFICATION OF STRATEGIC SPECIAL NUCLEAR MATERIALS TO DETER THEIR THEFT OR UNAUTHORIZED USE, (IRT-378-R, Nov. 6, 1975) (prepared for the U.S. Nuclear Regulatory Comm'n).
alpha radiation from U-235 and a negligible amount to that of Pu, toxicity may constitute only a minor problem. In process, a more serious concern is that purification may remove Tl\(^{208}\) and it would take at least ten days to reestablish a sufficient concentration for detectability. Co\(^{60}\) may evaporate in process, making it difficult to manage. The behavior of Y\(^{93}\) in the process stream is not known.\(^{12}\)

2. Neutron Spikants

Spiking fissile materials with neutron spikants has two major advantages over gamma-ray spikants: neutron shielding is very bulky and, therefore, more conspicuous than gamma-ray shielding, and moderated thermal neutrons (\textit{i.e.}, slowed-down neutrons) are easier to detect against normal background radiation levels than gamma rays.\(^{13}\)

Pu emits such large quantities of neutrons spontaneously that addition of a spikant to produce neutron emissions would be superfluous. U\(^{238}\), however, does not produce such a neutron emission so that it may be logical to add a neutron spikant if it is used in a nuclear energy fuel cycle. U\(^{233}\) fuels produce a level of gamma radiation sufficient to negate any need for consideration of neutron spiking or observation.\(^{14}\)

The most promising neutron spikant is californium-252 (Cf\(^ {252}\)). The addition of Cf\(^ {252}\) to U\(^ {235}\) fuels would increase the total reactivity of U\(^ {235}\) by 0.1\% and it would significantly increase the detectability of neutron emissions.\(^{15}\)

III. SPIKING FOR DETECTION AT DOORWAY MONITORS

A. Regulatory Requirements

The Nuclear Regulatory Commission (NRC) requires that facilities possessing significant quantities of fissile materials\(^{16}\) provide physical protection measures in addition to those required for other fixed site facilities.\(^{17}\) In that set of requirements, the NRC provides that:

Each individual, package, and vehicle shall be searched for concealed special nuclear material [fissile materials] before exiting from a material access area unless exit is into a contiguous material access area. \textit{The search may be carried out by a physical search or by use of

\(^{12}\) WEINSTOCK, \textit{supra} note 8, at II-5.

\(^{13}\) \textit{Id.} at II-22.


\(^{15}\) WEINSTOCK, \textit{supra} note 8, at II-5.

\(^{16}\) 10 C.F.R. § 73.60 (1980) defines “significant quantities” as “uranium-235 (contained in uranium enriched to 20 percent or more in the U-235 isotope), uranium-233, or plutonium alone or in any combination in a quantity of 5,000 grams or more computed by the formula, grams = (grams contained in U-235) + 2.5(grams U-233 + grams plutonium).”

\(^{17}\) General requirements for physical security at fixed sites not possessing significant quantities of fissile material are contained in 10 C.F.R. §§ 73.40, 73.50 (1980).
equipment capable of detecting the presence of concealed special nuclear material.\textsuperscript{18}

The regulations require further that:

Each licensee shall test and maintain intrusion alarms, physical barriers, and other devices utilized pursuant to the requirements of this section as follows:

(1) Intrusion alarms, physical barriers, and other devices used for material protection shall be maintained in operable condition.

(2) Each intrusion alarm shall be inspected and tested for operability and required functional performance at the beginning and end of each interval during which it is used for material protection, but not less frequently than once every seven (7) days.\textsuperscript{19}

The NRC regulatory guides\textsuperscript{20} provide guidance for licensees in meeting these requirements. Regulatory guides are suggestions from the NRC on how to meet regulatory requirements. They are not binding on either the NRC or its licensees.

In essence, a doorway monitor must be able to detect at least 0.5 g of Pu, 1.0 g of \textsuperscript{233}U, or 3.0 g of \textsuperscript{235}U shielded by at least 3 mm of brass. These sensitivities are not difficult to achieve as long as the shielding used is not greater than the specified amount. However, the use of thicker shielding or of material more effective in shielding than brass may greatly reduce the sensitivity of currently used doorway monitors, which, for the most part, are designed to detect gamma radiation, not neutron emissions.

To put those parameters in perspective, Willrich and Taylor in their seminal book on nuclear theft calculated that a reasonably sophisticated explosive mechanism would need approximately eight kilograms of Pu, 25 kg of \textsuperscript{235}U, or ten kg of \textsuperscript{233}U.\textsuperscript{21} The cruder the explosive device used, the more of each of these fissile materials would be necessary to create an explosion.

Another fact worth noting is that the ability to design a sophisticated device is very different from the ability to construct it. To make an analogy, the design of an internal combustion engine is very easy to obtain but building it would require knowledge of engineering, metallurgy, and machining. For most people, a home version would not run very long, if at all. Actually, construction of a nuclear explosive, even with sufficient fissile materials, is a substantial undertaking which, much like the homemade internal com-

\textsuperscript{18} 10 C.F.R. § 73.60(b) (1980) (emphasia added). "Special nuclear material" (SNM) is the term used by regulatory agencies to designate significant quantities of fissile nuclear materials capable of producing an explosion.

\textsuperscript{19} 10 C.F.R. § 73.60(d) (1980).


bustion engine, may not work. Still, the potential effects are devastating enough to warrant a very conservative assumption about the ability of nuclear thieves to construct an explosive device with their stolen material.

B. Effects of Shielding Against Doorway Monitors

Experiments have been performed to examine the effects of shielding certain amounts of fissile materials for covert removal through a doorway monitor. Assuming the use of gamma-ray detectors and a threshold alarm rate four standard deviations above background gamma radiation, a set of values can be arrived at for concentrations of various spikants which render a given mass of fissile material detectable.

Because U^{233} materials will always contain enough U^{235} to generate Th^{228}, they will (after several days) emit sufficiently strong gamma radiation to make shielding ineffective. Therefore, U^{233} materials are considered to be naturally "spiked" and their self-generated gamma radiation is adequate for detection. Given a maximum permissible employee dose rate of 2.5 mR/hr. at one foot, a 10 g sample of U-235 spiked with Th^{228} would be just detectable through a maximum of approximately 1 inch of lead.

The physical dimensions of shielding create an upper limit for someone concealing it on his person. It is unlikely that a person could carry a shield three inches thick without detection by an observer. Shielding may be more difficult for neutron spikants since, as discussed earlier, neutron shielding is very bulky and, therefore, more conspicuous than gamma-ray shielding. Plutonium already emits copious amounts of neutrons without any spikant while U^{235} does not. Thus U^{235} would be a more logical candidate for neutron spiking than Pu.

The high background level of neutrons at facilities processing fissile materials is a major problem in neutron detection. A background level ten times that of Brookhaven National Laboratory in Upton, New York, approximates that of a bulk handling facility for fissile materials. Data indicate that Pu is already adequately "spiked" with its own neutron emitters since less than 100 g of Pu can be detected through six inches of shielding by a neutron detector. U^{235} could be spiked with relatively small quantities of Cf-252 to give comparable protection.

The shielding material used in collecting these data was polyethylene. Other shielding materials and configurations may possess somewhat different shielding characteristics, but a basic problem in neutron shielding is that neutrons must be slowed down (moderated) in order to be efficiently

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22 Background gamma radiation varies greatly according to the environment. In a nuclear materials processing facility it might be well above normal levels.
23 This assumption has not been tested or verified.
captured. Polyethylene moderates and captures neutrons, but the use of two materials, one for moderation and one for capture, may increase shielding effectiveness. Once again, the size of the shielding configuration limits concealment so that a more efficient shield than polyethylene is impractically large.

C. Administration and Legal Restrictions

Normal day-to-day operations call for the use of techniques which amount to a search of all entering and exiting personnel and visual surveillance of personnel while in the facility. The NRC regulatory guides suggest that:

Searching of individuals can be carried out by means of hands-on search (“frisking”), or by means of devices which will detect the presence of weapons and explosives or SNM [fissile nuclear materials] concealed on the individual, or by a combination of both. The search should be conducted in a manner which (1) provides assurance that firearms, explosives, and other such contraband are not being carried into the protected area and that SNM is not being transported into a material access area and (2) minimizes inconvenience to the individuals being searched. The use of equipment capable of detecting weapons, explosives, or SNM is usually the preferable form of searching, since the use of detection devices avoids the personal imposition of hands-on search.24

The clear preference for avoiding the personal imposition of a physical search is most likely a response to judicial concerns that the least onerous means be used to assure that an individual is not violating access controls. The guide goes on to suggest “airport-type” weapons detectors, in addition to devices to monitor the presence of fissile materials.25

The practice of searching individuals who desire, for one reason or another, entrance to a restricted area is not without precedent. It has been widely used to prevent aircraft hijackings26 and courthouse violence.27 Both airport boarding searches and courthouse briefcase inspections have been extensively litigated and found to be reasonable, warrantless searches under the fourth amendment.28 The activities suggested by the NRC regulatory guides are somewhat analogous to measures previously litigated and will be examined in that light.

Access controls may include the use of “hands-off” personnel search devices, inspection of packages, use of change rooms, visual surveillance,

25 Id.
26 See, e.g., United States v. Albarado, 495 F.2d 799 (2d Cir. 1974).
28 Id.
patdown body searches (frisking), and strip searches including body cavity searches. Only “hands-off” searches and inspection of packages are addressed in this article. In addition, some considerations will be given to on-site response to a verified loss or theft.

1. “Hands-Off” Personnel Search Devices

The courts have dealt variously with constitutional issues arising from the use of a magnetometer, a device which can detect concealed weapons in airports, but the use of this type of device has been universally upheld as an “absolutely minimal invasion in all respects of a passenger’s privacy weighed against the great threat to hundreds of persons if a hijacker is able to proceed to the plane undetected.”

Courts have justified airport detection devices with statements that a “plane may become a weapon of mass destruction that no ordinary person would have any way of obtaining except through a hijacking.” The analogy to fissile material which is, in effect, a “weapon of mass destruction” which no ordinary person would have any way of obtaining except through theft is a strong one.

The courts have found the use of magnetometers an “absolutely minimal invasion of privacy” in which, “There is no detention at all; there is no probing into an individual’s private life and thoughts.” However, a magnetometer may not be used surreptitiously because the courts have insisted upon advance notice to passengers in all cases involving airport searches. The NRC regulatory guides provide for “posting of a sign in a conspicuous location . . . to . . . inform individuals requesting access into the protected area that they will be searched, and that any packages, etc., they wish to take into the protected area will also be searched.” While the use of a warning sign is not contemplated as a tool for obtaining “consent,” it does serve to negate any expectation of privacy that an individual may harbor.

The use of a magnetometer is not unlike the use of any electronic search device, including explosive detectors and fissile material detectors. The elements of the search are subject to essentially the same constitutional limitations regardless of the type of contraband the detection device is directed toward. Since the use of magnetometers at airports affecting millions of travelers every year has been upheld, there is little reason to suppose that courts would not allow the use of electrical remote detection devices to extend into

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30 United States v. Albarado, 495 F.2d at 806.
31 Id. at 805.
32 Id. at 806. (citations omitted).
the far more limited area of safeguarding nuclear facilities possessing fissile material with no fundamental change in present case law.

2. Inspection of Packages

The NRC regulatory guides state that:

No individual should be allowed to directly carry any package, valise, tool box, or similar hand-carryable item into the protected area or out of a material access area. Such objects should be handed to an attendant, guard or watchman who will check them and pass them into the protected area or out of the material access area.34

This type of activity has been upheld in the same context as the use of a magnetometer. In fact, detection devices may be used to screen parcels after inspection for shielding.

The courts have considered the search of carry-on luggage in the airport situation a reasonable search. "A pre-boarding screening of all passengers and carry-on articles sufficient in scope to detect the presence of weapons or explosives is reasonably necessary to meet the need."35

In the context of inspections of packages carried into a courthouse, the need to protect government personnel and property from destruction has been found sufficient to establish the reasonableness of the search. "When the interest in protection of government property and personnel from destruction is balanced against any invasion to the entrant's personal dignity, privacy, and constitutional rights, the government's substantial interest in conducting the cursory inspection outweighs the personal inconvenience suffered by the individual."36 The intent of the search is also considered germane to its reasonableness:

[The persons whose packages are inspected generally fall within a morally neutral class. Because everyone carrying the enumerated parcels is required to have them inspected, the inspection is not accusatory in nature and the degree of insult to the entrant's dignity is minimal. Thus it cannot be said that a finger of suspicion is unfairly or arbitrarily being pointed at an individual as falling within a "highly selective or inherently suspect" group.37

There is little reason to believe that the courts would view as unreasonable the inspection of packages and parcels in the much more limited context of facilities containing fissile nuclear materials, when these techniques have been upheld in airport and courthouse contexts.

3. Response to Emergency

The NRC regulatory guides stipulate simply that in the event of an

34 Id.
35 United States v. Davis, 482 F.2d 893, 910 (9th Cir. 1973).
37 Id. (citations omitted).
emergency "all individuals should be searched for concealed SNM [fissile] material before being released from the protected area or collection area." No other stance is taken by the NRC concerning the scope of the search, which could encompass anything from the use of a electrical detector to a strip search and body cavity examination. Nowhere in the regulations or guides is interrogation mentioned as a response to a shortage or theft. It has been suggested in the literature that substantial pressure for detention, search, and interrogation of employees may lead to such activities if a sudden shortage is recognized. The scope of this article is limited to the use of electrical, remote devices and, as such, most of these concerns are not addressed here. There is clearly a need for guidance from the NRC on this problem, however.

D. Conclusions

Where an authorized person diverts fissile nuclear material, it must be assumed, for the sake of being conservative, that the diversion will occur incrementally over a period of time. An authorized individual may, for example, take a small quantity of fissile material out of a process stream, place it in a prefabricated shielded container, and smuggle the container past a doorway monitor. Over a period of time a sufficient quantity of fissile material could be accumulated outside the facility to fashion a crude explosive. The type and quantity of material diverted depends on the facility in question. The better the quality of material accountancy, the smaller the maximum quantity incrementally diverted must be to go unnoticed by material accountants.

Highly enriched uranium (HEU) which contains sufficient uranium-235 to be fissile would be present at some enrichment facilities and in fuel nuclear cycles utilizing HEU fuels. Plutonium would be present in chemical reprocessing facilities, plutonium recycle fuel facilities, and fast breeder reactors. U\(^{233}\) may be present in reprocessing facilities associated with thorium-based nuclear fuel cycles and subsequently in reactor fuel.

The threshold for judging a material to be "detectable" in this discussion is reached when sufficient shielding would be too large to conceal from a doorway observer.

Highly enriched uranium, defined as uranium with greater than 20% U\(^{235}\), is virtually impossible to detect in small quantities by gamma-emission observation. One-quarter-inch thickness of lead can effectively shield a few hundred grams of HEU, although the shielding would be very heavy. One half inch of lead shielding would allow a multi-kilogram quantity of U\(^{235}\) to be successfully smuggled past a doorway monitor.

This phenomenon suggests that HEU may be a good candidate for the

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89 Dyk, supra note 29, at 29.
gamma-ray spikants suggested (Th$^{238}$, Co$^{60}$, and Y$^{88}$) to increase its detectability. The higher energy of Th$^{238}$ appears to make it the most attractive except that its half-life is short (approximately 2 years). If that time period corresponds with the maximum residence of the material at the facility in question then spiking with Th$^{238}$ may be desirable. Co$^{60}$ has a longer, and therefore more convenient, half-life (approximately 5 years), but its lower emission energy would necessitate a larger quantity of spikant. Y$^{88}$ combines a short half-life (approximately 0.3 years) and low energy, making it unsatisfactory.

It may be more desirable to spike HEU with a neutron-emitting spikant. HEU does spontaneously emit neutrons, but at a rate too low to reliably detect. The addition of Cf$^{252}$ to HEU would make it observable in a portal situation even through bulky shielding and would add to its radioactivity (and, therefore, health-physics problems) by only 0.1%. A problem with this approach, however, is that most doorway monitors currently in use are set up to detect only gamma emissions. In any event, unspiked HEU can be smuggled past most current doorway monitors with only moderate difficulty.

U$^{233}$ fuels which have aged several days since purification emit very strong gamma radiation. The thickness of shielding necessary to render even gram quantities of U$^{233}$ undetectable would be far too large to conceal and would certainly be noticed by the security guard stationed at the doorway.

Plutonium in a nuclear fuel cycle can have various emission characteristics depending on the burn-up of the fuel while in the reactor. However, it can be calculated that a one-inch lead shield could allow 50 to 100 grams of Pu to escape detection by a gamma emissions detector. This suggests that gamma-ray spikants may be desirable. As in the case of HEU, Pu can be spiked with Th$^{238}$ to render it more detectable.

For neutron detection, no spikant is necessary. Pu emits copious neutron radiation which is very difficult to shield at a close, controlled range. A 100 g quantity of Pu could be detected in a doorway situation even through six inches of neutron shielding. It is not credible to assume that six inches of shielding (at minimum, a 12-inch sphere) would be sufficiently inconspicuous to escape observation at the portal. As in the case of HEU, current doorway monitors are designed, for the most part, as only gamma emission detectors and unspiked plutonium could be smuggled past most doorway monitors with moderate gamma shielding.

IV. LOCATING CONTRABAND NUCLEAR MATERIALS

A. Methods of Detection

Detection of radioactive emissions in a search outside the facility
boundaries is significantly different from doorway detection. Various factors such as changing background radiation, increased source-to-detector distances, and potential lack of control over count radiation rates contribute substantially to greater difficulty in locating nuclear materials. It is difficult to place realistic boundaries on the dimensions of an area search for contraband fissile materials. The following discussion of possible methods of locating radioactive emissions will be followed by an analysis of search scenarios in order to examine the legal and administrative implications of such searches.

1. Searching for Gamma Radiation

Several factors contribute to the difficulty of locating contraband fissile materials by observing gamma radiation. These include: 1) the energy of the emission; 2) the self-shielding of the fissile material; 3) the attenuation of the emission by distance, air, or other intervening materials; 4) the background gamma-radiation levels; 5) the characteristics of the equipment available; and 6) the time intervals used in searching. These factors are examined in the following sections.

a. Self-Shielding and Emission Energy

Nuclear material will absorb some radiation emitted by itself so that while nuclear reactions which produce gamma rays will be occurring, some of those gamma emissions will never leave the mass of fissile material in question. This phenomenon is referred to as "self-shielding." Shelf-shielding can be very significant in affecting the emissions of Pu, actually absorbing most emissions generated in its mass.

b. Attenuation of Gamma Radiation

Contraband fissile material will probably be secreted so as to minimize the probability of detection, either visually or with radiation detectors. It must be recognized that just air between a radiation source and a detector will by itself attenuate gamma radiation significantly. As other materials intervene, shielding effects increase dramatically. When the source is behind 100 cm of concrete, emissions decrease by several orders of magnitude and are commensurately difficult to detect.

c. Background Radiation

In order to alert an observer to the presence of nuclear material, the radioactive source must have an emission sufficiently large to be detectable above normal background radiation. The principal sources of background

40 Weinstock, supra note 8, at III-3.
gamma radiation are radioactive minerals in the ground, radioactive materials in the air, and cosmic radiation from outer space. A major problem in any search scenario is that background radiation levels often change substantially from one location to another. In general, the higher the background level the more difficult detection becomes.

d. Detector Efficiency
The type of detector dictates actual efficiencies. In general, the efficiency of detection decreases as higher energy emissions are sought.\textsuperscript{43} Exact efficiencies of detectors likely to be used in a search for contraband nuclear materials are classified as national security information and are withheld from the public.

e. Time Intervals and Search Conditions
An effective search for radioactive sources requires that the time interval for observation at a particular site be of sufficient duration to collect enough emission counts to allow a reliable statistical analysis. The longer the duration, the more accurate the detection system. If an airborne detection system were used, time intervals would necessarily be very short and the results far less reliable. If normal ground transportation is used (e.g., a van or an automobile) longer intervals are possible and, therefore, greater reliability.

The objective of the detection system is to identify gamma radiation sufficiently greater than the previous background counts to indicate the existence of some extraneous source. Here, we assume that the previously collected counts contain only background radiation. The smaller the standard deviation of the background counts (i.e., among sample intervals) the less extraneous gamma radiation is necessary for detection. In practice, standard deviations in background when measured from a moving vehicle may be very high, hence reducing the probability of detection. If only air intervenes between the source and detector the energy of the gamma source is not very important. However, as shielding is introduced high-energy gamma radiation has advantages over lower energies.

Establishing radiation background levels for many areas of the United States has been accomplished by "photographing" large land areas with equipment capable of seeing radioactivity. If a theft occurred, new pictures could be taken and new radiation sources checked out. The extent and current accuracy of these picture files is not clear, but they represent a reasonable way to overcome, to some extent, the problem of time intervals.

f. Potential Gamma-Source Spikants
The literature has suggested four gamma radiation sources as potential

\textsuperscript{43} See, e.g., S. Vegors, \textit{Calculated Efficiencies of Cylindrical Radiation Detectors} (IDo No. 16370, 1958).
spikants for location of contraband fissile materials: cobalt-60, yttrium-88, cesium-137, and thorium-228.

The higher the radioactivity of the spikant, the less of it is necessary for detection purposes. Higher energy emissions are desirable from the standpoint of defeating shielding, and the half-life must be taken into account since the passage of time will degrade detectability at a specific rate.

Y$^{88}$ has the highest radioactivity but its half-life is relatively short (approximately 108 days). Co$^{60}$ has a low radioactivity and low emission energies and a medium (approximately 5.3 years) half-life. Cs$^{137}$ has a long half-life (approximately 30 years) but a low energy emission and low radioactivity. Th$^{228}$ has a high radioactivity and a high energy emission, but a short half-life (approximately 1.9 years).

It is apparent that Y$^{88}$ is desirable over a short term because of its high radioactivity, but its activity decreases quickly as time passes. Cs$^{137}$ may have the best potential as a spikant, but its low radioactivity and emission energy require the use of very large quantities. Co$^{60}$ has a reasonably long half-life for purposes of spiking, but its low emission energy dictates that relatively large quantities of this spikant would also be necessary. Th$^{228}$ has a relatively short half-life (about seven times greater than Y$^{88}$), but its high radioactivity and much higher emission energy make it attractive as a potential spikant.

2. Neutrons

The detection of neutrons is similar to the detection of gamma radiation, with a few specific exceptions. The source strength of neutrons is not as important, and self-shielding is not significant. Attenuation of neutrons in air is more appreciable than that of gamma radiation.

a. Attenuation of Neutrons

Neutrons emitted from radioactive material have an extremely high velocity. The oxygen and nitrogen molecules in air are quite effective at slowing down these fast neutrons. However, neutrons may travel a long distance (approximately 1 km) in air before becoming thermalized (slowed down). A slow neutron is captured, or absorbed, quickly by nitrogen in the air. If neutron emissions travel about 100 to 300 meters in air most neutrons will still be fast although their energies will be significantly altered.

Calculation of the attenuation of neutrons by concrete is difficult because of the variations in composition. 100 cm of “average” concrete

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44 Weinstock, supra note 8, at III-13-17.
45 Thorium-228 is not in itself a spikant, but its daughter product, thallium-208, produces high energy emissions once in equilibrium.
46 Weinstock, supra note 8, at III-17-22.
CONTRABAND NUCLEAR MATERIAL

will generally attenuate a neutron flux by about an order of magnitude. This value is approximate, but indicates that concrete can be used effectively to shield neutrons from detection by remote radiation detectors.

b. Neutron Detection Systems

Neutron detection systems look for slow neutrons. Since neutron emissions at their source are fast, some medium must be used at the detector site to moderate (slow down) fast neutrons. Generally, as discussed before, this is accomplished with polyethylene which surrounds the actual detection medium. A typical detection medium is boron triflouride (BF$_3$) which will produce, when a neutron enters the device, a measurable electric charge in the medium. Neutron detection systems, therefore, will typically observe neutrons by first slowing them down with polyethylene and then by capturing them in a BF$_3$ medium. A detection system will be set to identify a neutron count rate several times (e.g., four) above the standard deviation for successive background counts.

c. Background Radiation

In general, the count rate of background neutron radiation is very small when compared to gamma radiation. This phenomenon results in a smaller standard deviation for neutron counts than for gamma radiation and, therefore, more accurate measurements.

d. Potential Neutron-Source Spikants

The two neutron spikants suggested in the literature are curium-244 and californium-252. Both elements have high neutron emissions, but their half-lives differ significantly (17.6 and 2.65 years, respectively).

3. Methods and Reliability

Fissile material, stolen and secreted so as to avoid detection, would be shielded and hidden from sight. If gamma radiation detection were used as a means of recovery, distance would prove an unsurmountable barrier to searching a large area expeditiously. Variations in background counts coupled with scenarios involving intervening distance or materials would make detection of moderately shielded fissile material difficult, even if the material were spiked. A search scenario must include an assumption that some shielding would be attempted, making distance and count-rate intervals the only conditions capable of adjustment. Therefore, in scenarios including buildings and general congestion (e.g., in an urban environment) it would be possible to locate contraband fissile material only by minimizing distances. It can be expected, therefore, that some invasion of privacy would necessarily occur during a search for contraband fissile materials.

Neutrons can be shielded quite easily when concealment on one's person is not a factor. Several feet of water (e.g., a swimming pool) would conceal neutron radiation from detectors. Detectors aimed at observing
excessive neutron radiation would benefit as does gamma ray detection from reduced source-to-detector distances. Either method, therefore, would require, as the exigency increases, greater invasions of privacy.

B. Legal Requirements and Restrictions

1. Jurisdiction and Background

Since the Federal Bureau of Investigation has jurisdiction over all incidents, including nuclear threats, which involve suspected or actual violations of federal laws, it would have primary jurisdiction and responsibility for directing and coordinating federal operations in the event of hostile actions against nuclear facilities or material and for the recovery of fissile nuclear material. If required, the DOE would support the FBI by providing Nuclear Emergency Search Teams (NEST) responsible for locating and identifying radiation-producing materials. The DOE and the Department of Defense (DOD) would work together in many ways, including the DOE/DOD Joint Nuclear Accident Coordinating Center, which exchanges and maintains information about radiological assistance capabilities and coordinates assistance in incidents involving radioactive materials.

Personnel supporting the recovery plans are organized into NEST teams and include representatives from the DOE laboratories and contractors. Each of these agencies has developed a detailed plan for supporting the teams with ground and airborne detection equipment, with logistic and communications support, and with reinforcement by representatives of the FBI and local law enforcement agencies. In addition to the NEST teams, a wide variety of technical specialists is also available to support an immediate recovery operation.

The foremost problem in recovery activities may be the interference with civil liberties involved in a frantic search for material, which is known only to be in a non-particular area (i.e., a certain city block or even a city itself). Integral to the entire recovery issue is a decision as to which sort of legal authority (and, therefore, legal procedure) should govern the recovery operations. Recovery operations could fall under any of three general sources of authority: national security, ordinary crime, and emergency. Each authority carries its own restraints and freedoms in its response to criminal activity. It is questionable whether recovery activities could be classified as protecting health—unless the material is believed to be missing because of an innocent mistake. The literature does not suggest that innocent mistakes are to be assumed, however, in view of the potential consequences of a successful theft.

Regardless of the authority assumed for recovery operations, it is difficult to imagine a wide-scale search operation which would not result in a general suppression of some constitutional rights. The right most likely to be violated is freedom from unreasonable search and seizure with neither warrants nor due process. Two other areas of concern can be raised: a voluntary or involuntary media "blackout" of the recovery operation, and the possibilities of martial law and potential evacuations. These considerations lie outside the scope of this article, but must be weighed in any final analysis.

The sources of authority (i.e., national security, ordinary crime, and emergency) must be examined separately, because the outcome of judicial review of recovery activities may depend on which source of authority was initially invoked.

2. Sources of Authority

a. National Security

The elements of national security require that a warrant be obtained for a search unless the thief is an agent of or acting in collaboration with a foreign power. The thrust of court decisions in this area is that a foreign agent’s dwelling may be entered or his telephone tapped without the formality of a warrant.49

If a recovery operation is provoked by concern that another nation is actually attempting to subvert the United States government, then drastic measures would be justified under clearly established constitutional doctrines. The most widely noted statement by the Supreme Court upholding broad administrative powers in a national emergency is the decision supporting the detention of Japanese-Americans during World War II.50 During that period, the commanding general of the western command, United States Army, directed that all persons of Japanese ancestry be excluded from a "military area." This area encompassed the home of the petitioner, a Japanese-American who had knowingly violated the order. The Supreme Court stated that:

[W]e are unable to conclude that it was beyond the war power of Congress and the Executive to exclude those of Japanese ancestry from the West Coast war area at the time they did. True, exclusion from the area in which one’s home is located is a far greater deprivation than constant confinement to the home from 8 p.m. to 6 a.m. Nothing short of apprehension by the proper military authorities of the gravest imminent danger to the public safety can constitutionally justify either.51

Two important facts are worth noting here, however. First, the action

51 Id. at 217-18.
was taken pursuant to a declared state of war. An act of Congress had authorized the President to promulgate exclusion orders and curfews during the crisis.⁵² On the basis of an executive order, several military orders, such as those noted above, were held to be justifiable intrusions upon civil liberties.⁵³ In the event of a recovery operation, it is not clear that executive measures such as relocation of populations would be sustained in the absence of a congressional mandate, even if foreign involvement were a factor.

Secondly, the decisions upholding relocation of Japanese-Americans have been widely criticized. It is possible that in a similar situation today the courts and society in general would be more sensitive to considerations of civil liberties. However, a recovery operation necessitated by foreign involvement would enjoy wide public support. Furthermore, such a recovery operation would not be aimed at any particular racial class, but at the broad class of those whose safety is genuinely in danger. What such a recovery operation would entail is not entirely clear, but it is unlikely to be more intrusive than the relocation of Japanese-Americans during World War II. If there is foreign involvement and imminent danger of a nuclear incident, it seems likely that, in view of its history, the Court would uphold intrusive recovery actions.

b. Ordinary Crime

There would be overwhelming pressure to turn the country upside down in the event of a successful theft of fissile material. The Supreme Court’s simple dictum that the courts must balance “the need to search against the invasion which the search entails,”⁵⁴ has led to differing views of what is reasonable in times of criminal crisis.

In 1974, the San Francisco police detained and questioned blacks, in the absence of specific grounds, during a city-wide search for the perpetrators of the so-called “Zebra” murders. Federal District Judge Zirpoli granted an injunction forbidding these activities, even though many murders had occurred and it was known only that the suspect was black.⁵⁵ Judge Zirpoli had looked to a case in Baltimore in 1966⁵⁶ where the police had searched over 300 private dwellings occupied almost entirely by blacks, without probable cause or warrants. They were searching for two blacks believed to have killed one police officer and wounded another during a liquor store robbery. In enjoining such searches, the court observed:

This case reveals a series of the most flagrant invasions of privacy

⁵² Id. at 216-17.
⁵³ Id. at 223-24.
ever to come under the scrutiny of a federal court.... If denying relief in these circumstances should be held a proper exercise of judicial restraint, it would be difficult to envision any case justifying judicial intervention. The parties seeking redress have committed no acts warranting violation of the privacy of their homes; there has never been any suspicion concerning them or their associations.\(^57\)

On the other hand, a federal court in New York upheld the search of a suspect's apartment without a warrant even in the absence of any of the exceptions to the warrant requirement recognized by the Supreme Court.\(^58\) The case is interesting because of certain similarities to a hypothetical recovery operation for contraband fissile material. The day after four major New York City buildings had been struck by explosions, the police arrested a suspect in possession of dynamite bombs believed to be intended for the destruction of army property. Shortly before the arrest, the police had searched the apartment of a friend of the suspect, allegedly to discover either other explosives or information about the location and timing of other explosions. The court held the search lawful because "the consequences feared [by the FBI] had to be considered in the atmosphere of seven terrifying explosions which had recently occurred in the city of New York."\(^59\) Of course, this case entailed the search of only one person's apartment, but, nonetheless, the court justified an otherwise unreasonable search by balancing it against the occurrence of "terrifying explosions."

At the crux of the recovery issue, if thefts of fissile nuclear material are to be treated as ordinary crime, is the applicability of the warrant requirement and its particularity requirements. If evidence is procured by a means which violates either the warrant requirement or the particularity requirement, it is not admissible in a criminal proceeding of any kind.\(^60\)

The applicability of the warrant requirement to recovery operations is not clear, because of the lack of precedent in the area of thefts of fissile material. Of course, this absence of precedent necessitates a speculative approach to predicting what judicial standards would be applied to a recovery operation. The Supreme Court has found the warrant requirement applicable to searches and inspections performed for public health and safety. The essentially non-criminal nature of a health and safety inspection was not found to justify dispensing with the warrant requirement: "It is surely anomalous to say that the individual and his private property are fully protected by the Fourth Amendment only when an individual is suspected of criminal behavior."\(^61\)

\(^{57}\) Id. at 201-2.


\(^{59}\) Id. at 832.

\(^{60}\) See, e.g., McDonald v. United States, 335 U.S. 451 (1948).

\(^{61}\) Camara v. Municipal Ct., 387 U.S. at 530.
The warrant requirement, if the recovery operation is conducted as a criminal investigation, will probably be applicable. There is little case law which indicates that the judiciary would dispense with it in a search of this nature, regardless of the scope, unless it is an emergency as discussed below. The fourth amendment states that: "No Warrants shall issue, but upon probably cause, supported by oath or affirmation, and particularly describing the place to be searched, and the persons or things to be seized." This mandate displays the constitutional framers' absolute opposition to "general warrants" or "writs of assistance." The purpose of the fourth amendment "is to safeguard the privacy and security of individuals against arbitrary invasions by government officials." General warrants are thought to violate this tenet by leaving the decision to invade a person's privacy to the untrammeled discretion of a police officer.

The Supreme Court historically held that the warrant must be particular enough to allow the officer, "with reasonable effort [to] ascertain and identify the place intended." In 1967, the Supreme Court announced a test for the reasonableness of an inspection for health and safety purposes. First, the purpose of the inspection program is to prevent the "development of conditions which are hazardous to public health and safety"; second, the only test of the reasonableness of a search is to balance "the need to search against the invasion which the search entails"; third, under the balancing test, the public interest in abatement of dangerous conditions justifies the issuance of warrants aimed at entire areas where "it is doubtful that any other canvassing technique would achieve acceptable results."

This has led some to conclude that the courts would be willing to sacrifice the particularity requirement, to a degree, in order to maintain some level of judicial control over the search. This may be the only method available to the judiciary in the event of a massive, sweeping search for stolen fissile nuclear material. It is somewhat doubtful that such a search would be declared unlawful or be enjoined in light of the dangers involved.

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62 U.S. CONST. amend. IV.
63 Camara v. Municipal Ct., 387 U.S. at 528.
64 Steele v. United States, 267 U.S. 498, 503 (1925).
65 Camara v. Municipal Ct., 387 U.S. at 523.
66 Id. at 535.
67 Id. at 536-37.
69 The Supreme Court has made it clear that domestic security surveillance programs were overbroad relative to the dangers they sought to avert, but this attitude probably would not extend to clear-cut cases of extreme emergency. See, e.g., United States v. United States Dist. Ct., 407 U.S. 297, 324 (1972).
In absence of a legislative statement or foreign involvement, the recovery operation must be viewed as an ordinary criminal investigation. Thus, it would be for the judiciary to accept or reject the loss of fourth amendment rights as a trade-off against a possible nuclear explosion or dispersal of toxic radiological material. It is difficult to imagine the courts enjoining a recovery operation in light of the possible consequences.

c. Emergency Power

The Supreme Court has upheld the suppression of constitutional rights in emergency situations. Emergency exceptions have been held constitutional for seizure, without due process, of tubercular cattle\textsuperscript{71} and unwholesome food,\textsuperscript{72} for the enforcement of the compulsory smallpox vaccination program\textsuperscript{73} and health quarantine,\textsuperscript{74} for the collection of the internal revenue of the United States,\textsuperscript{75} for protection against economic disaster of a bank failure,\textsuperscript{76} and for protection of the public from misbranded drugs.\textsuperscript{77} The Supreme Court has outlined requirements of an emergency situation which would justify a suppression of constitutionally guaranteed rights: the action must be "directly necessary to secure an important governmental or general public interest"; there has to be a "special need for very prompt action"; the state must keep "strict control over its monopoly of legitimate force"; and the person initiating the seizure must be a government official responsible for determining, under a narrowly drawn statute, that the action was "necessary and justified in the particular instance."\textsuperscript{78} The first requirement would be fulfilled in the event of a theft of fissile material. The recovery of stolen fissile material is most definitely an important governmental and general public interest. The second requirement would be satisfied because there would be a "special need for very prompt action." Only the third requirement of a narrowly drawn statute and a designated responsible official would be lacking in a recovery operation. One possible solution to this problem would be so-called "emergency legislation," a response to public necessity which has received some attention in the courts over the years. In ruling on an exercise of eminent domain by the legislature, a Connecticut court has stated that:

Public necessity . . . is that urgent, immediate public need arising from existing conditions which, in the judgment of the legislature, justifies a disturbance of private rights that otherwise might be legally exempt from such interference. The term is, therefore, a relative one.

\textsuperscript{71} Kroplin v. Truax, 119 Ohio St. 610, 165 N.E. 498 (1929).
\textsuperscript{72} N. Am. Cold Storage Co. v. City of Chicago, 211 U.S. 306 (1908).
\textsuperscript{73} Jacobson v. Massachusetts, 197 U.S. 11 (1905).
\textsuperscript{74} Compagne Francaise de Navigation a Vapeur v. La. St. Bd. of Health, 186 U.S. 380 (1902).
\textsuperscript{75} Phillips v. Commissioner, 283 U.S. 589 (1930).
\textsuperscript{76} Fahey v. Mallonee, 332 U.S. 245 (1946).
It determines in each case that may arise the relation of the duty implied in the broad grant of legislative power to promote by appropriate action the interests of the commonwealth to the limitations of that power established for the protection of private rights.  

And in 1939, a New York court suggested that "emergency legislation" is an integral step in legislative progression in the tradition of the common law, providing for the changing needs of an ever more complex society:

Almost every legal innovation has been the product of "emergency"—a condition that deviates from antecedent experience and for which the usual forms of law seem inadequate to serve the public order. Such conditions or emergencies, step by step, gave stimulus to the creations, to the new writs and to the new pleas of the common law during all its vital development. The statutory "emergency" of the last decade in this country has frequently been a legislative fiction, but such fictions to provide treatment for new conditions are in the best tradition of the common law. A declaration of emergency by a legislative body under recent legislative practice is usually a recognition that new conditions require new treatment under regulations that might be and frequently were long continued by successive enactments from time to time. It was inevitable that these new devices of legislative action, having once been accepted as "emergency" legislation and having met the test of experience would in time, and where successful in practice, be accepted as common and legitimate fields of permanent legislation.

However, more recent cases have tended to limit the operation of "emergency" legislation where civil liberties are jeopardized. In disallowing the imposition of license fees for importation of oil required by presidential proclamation without any procedural prerequisites, a federal court noted that:

More fundamentally, this case raises a question about the way Government should operate when responding to crisis. Neither the term "national security" nor "emergency" is a talisman, the thaumaturgic invocation of which should, ipso facto, suspend the normal checks and balances on each branch of Government. Our laws were not established merely to be followed only when times are tranquil. If our system is to survive, we must respond to even the most difficult of problems in a manner consistent with the limitations placed upon the Congress, the President and the Courts by our Constitution and our laws.

From this history, it is apparent that the courts would have great difficulty in assessing legislative authorization for mass recovery operations. The public interest in recovering stolen fissile material would have to

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be weighed against the invasion of constitutional rights which the operation entailed.

Warrantless searches outside of a legislative scheme are most often justified through the emergency doctrine: instances when police action is called for and time is of the essence. The scope of an emergency search is limited by the extent of the emergency which initiated it. During an emergency search, authorities have the right to seize any evidence in plain view.

The emergency doctrine emerged in 1948 when the Supreme Court held that under exceptional circumstances authorities may dispense with the need for a warrant. The search in question must be shown to be absolutely necessary. The timeliness of the search and the need to avoid delay are very important since it is the immediate need to search which justifies the exception to the warrant requirement.

There are five broad categories of circumstances when warrantless emergency search is legal: (1) fire emergencies, (2) hot pursuit, (3) loss or destruction of evidence, (4) report of noise or suspicious odor, and (5) report of crime or injury. Only hot pursuit and report of crime or injury apply directly to a recovery operation.

The hot pursuit doctrine allows authorities to follow a fleeing felon into a building which he has just entered. This doctrine is somewhat limited in that a warrantless search after the arrest can be made only for weapons used in the crime or against authorities. The Supreme Court has further stated that the warrant requirement does not require authorities to delay an investigation if delay would gravely endanger their lives or the lives of others. Courts have rejected warrantless searches beyond that. For example, the courts rejected the application of the hot pursuit doctrine when a defendant was arrested in his house and the arresting authorities searched his attic on the pretense of looking for snipers.

Warrantless crime scene searches can be conducted only when there is reason to believe that there may be loss or destruction of evidence. There is no exception to the warrant requirement predicated on the seriousness of the crime. The courts have allowed authorities to make a "walk-through" search of premises to check for victims or potentially dangerous persons still present. When a person is reported mysteriously missing, war-

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82 McDonald v. United States, 335 U.S. at 451.
rantless room-to-room searches of hotels and other business premises have been allowed.  

C. Direct Constitutional Impacts

1. The Fourth Amendment Concerns

The reasonableness of a search is the controlling factor in whether the search is held legal or illegal. While the primary objective of a recovery operation would be the recovery of the stolen fissile material, it would also be highly desirable that once the contraband material has been recovered, it should be admissible as evidence against those who stole it. The test for reasonableness has been laid out by the Court: "Unfortunately there can be no ready test for determining reasonableness other than by balancing the need to search against the invasion which the search entails."

With this test in hand, a two-pronged approach to the problem could be taken. A recovery operation may present an unprecedented "need to search" which would in itself render the search reasonable. The all-or-nothing approach to the exclusion rule taken by the courts, which makes any contraband found in a lawful search admissible regardless of its relation to the reason for the search, may become outmoded because of the presence of a potential or real need to search as great as the need to search for stolen fissile material. Several commentators have suggested that if evidence unrelated to the recovery operation were turned up (i.e., contraband which is not related to nuclear theft) it might be legislatively made inadmissible in a criminal proceeding. This legislative action would have the effect of lessening "the invasion the search entails" by protecting "third-party" interests. However, it would not eliminate the tremendous invasion of privacy a recovery operation could present to third parties. But, it could be forcefully argued that the "expectation of privacy" would be far less in an emergency search for stolen fissile material since, presumably, most people would favor its recovery and would, in fact, welcome measures aimed at locating it.

The desirability of excluding evidence not related to the recovery operation is great. The courts would not be forced to choose between finding the search reasonable (allowing individuals innocent of nuclear theft, but guilty of unrelated crimes, to be tried on the basis of a search conducted for contraband nuclear materials) and finding it unreasonable (making prosecution of the suspected thieves difficult because of the inadmissibility of the evidence of their theft—the recovered nuclear material). The only

89 See COMMITTEE ON CIVIL RIGHTS, LEGISLATURE RESPONSE TO ZUCKER V. STANFORD DAILY, 35 REC. OF THE ASS'N OF THE BAR OF THE CITY OF N.Y. 415-417 (1980); Dyk, supra note 29, at 105; Barton, supra note 48, at 23.
precedent for finding evidence secured in a legal search inadmissible is in cases where the evidence has been found in a manner inconsistent with the particularity of the search:

The scope of the search must be strictly tied to and justified by the circumstances which rendered its initiation permissible. In other words, it is, and indeed for preservation of a free society must be, a constitutional requirement that to be reasonable the search must be as limited as possible commensurate with the performance of its functions.\(^9\)

Even though contraband other than fissile materials may be found, the "scope" of the search may not have been violated, since a small parcel of fissile material may be difficult to find and, therefore, a thorough search may be required. Perhaps the courts will find that the fruits of such a search must also be reasonably "tied to and justified by the circumstances which rendered its initiation permissible." Of course, this suggestion amounts to a drastic change in the current approach to search and seizure, but a drastic change may be necessary. It is reasonable to suggest that such a change in the rules of criminal evidence would better be initiated through legislation than in the courts, especially since the post-event environment may be one which would foster radicalism in the judicial response.

2. Due Process Concerns

Constitutional due process requires that no person be deprived of life, liberty, or property without notice and an opportunity to be heard. This constitutional requirement can be circumvented if certain conditions exist. These conditions, outlined above,\(^9\) have been extended to cases where there exists a compelling state interest, special reason for prompt action, and statutory authority for the intrusion given to a designated official.\(^9\) The NRC lacks at present both the statutory authority and the designated official. If the NRC were to take steps toward satisfying these requirements, a more orderly recovery operation with fewer undesirable legal consequences should result.

D. Potential Scenarios

The aspects of a recovery operation which may affect civil liberties are distinct from other nuclear safeguards activities in two respects. First, they may never be used. Those activities selected in a recovery operation exist only as plans in the unlikely event of theft or loss of fissile material. Secondly, they possess the greatest potential for altering our present understanding of civil liberties. In the event of a successful theft, unprecedented activities may be necessary to prevent great destruction. For these reasons, constant reformulation of planned recovery activities through research and de-

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\(^9\) United States v. Albarado, 495 F.2d at 807 (Emphasis in original; citations omitted).

\(^9\) See text accompanying notes 71-77 supra.

\(^9\) See text accompanying note 78 supra.
development of search techniques should be pursued. If all nuclear material could be absolutely and easily located at all times—through the use of techniques such as radioactivity scans—wholly different and possibly less onerous recovery techniques might be feasible. This article has also raised the possibility of spiking radioactive material for purposes of increasing detection capabilities.

Since response plans are not made public, it is important for us to focus upon the most intrusive conceivable elements of a hypothetical operation in order to appreciate the potential impact of such a recovery operation. Possible responses include area searches and perimeter searches, as well searches of pedestrians and vehicles.

1. The General Legal Characteristics of a Search for Contraband Fissile Material

a. Area Searches

If a quantity of contraband fissile material were known to be within an area of only a few blocks, pressure to thoroughly search the dwellings in that area would be tremendous. Barton, in addressing the problems presented by an area search, suggests that:

It is . . . likely that even in a nuclear emergency, such a search (or an area warrant) would be struck down. Nevertheless, in airport search cases, a perceived overwhelming necessity dictated a change in the law. And public opinion would probably support such a change in the law. If the courts were to expand the emergency exception to permit area searches during nuclear emergency, the implication would be much greater freedom for area searches in any riot or terrorist blackmail situation. If, instead, the courts were to weaken the probable cause or particularity requirements for the issuance of warrants, the implication could be to expand general search powers enormously.93

This statement fairly represents the doctrinal choice which would be presented to the courts if many dwellings were entered in an uncertain effort to recover a missing quantity of fissile material. Declaring the search unlawful may trigger tort liability for officers conducting the search,94 but this problem is minimized by the Court's ruling that "good faith and probable cause" are acceptable defenses in such cases.95

In the absence of any further legislation or rule-making on recovery operations, the courts' choices in dealing with a recovery process are limited

93 Barton, supra note 48, at 24.
to: declaring the search unconstitutional and attempting to define what circumstances or statutes might make a recovery search acceptable; expanding the emergency exception in search and seizure requirements to allow for warrantless searches in emergency situations involving a risk as great as that in a nuclear incident; or fashioning a warrant which would lessen both the probable cause requirement and particularity requirement of present warrants.

Undesirable ramifications of operations for recovery of stolen fissile materials could be lessened if the NRC were to establish guidelines on how evidence should be treated and publicly designate a government official to head the search. Of course, the search itself would still be onerous, but there would be no impetus for the courts to rule on its validity if no prosecutions were sought. If prosecutions of indicted thieves of recovered fissile material were the only ones sought, the court would have to rule on the admissibility of the contraband fissile material as evidence. Perhaps the statutes protecting such materials could be amended to allow less difficulty in prosecutions in the absence of the stolen material as evidence. In any event, if many prosecutions were sought on the basis of contraband seized during the search, but not related to the recovery operation, the courts would almost certainly rule the search unconstitutional.

No questions are raised in this article concerning the forces that would be involved in such a search nor the tactics that would be used. These issues are not directly related to civil liberties but must, nonetheless, be decided in advance of a recovery operation. The courts have shown a clear preference for prior planning and accountability.

In the event of a widespread area search requiring entry into dwellings, it may not be possible to fulfill the prior planning requirement. There are two options if the courts were to accommodate this activity. The emergency exception to the warrant requirement could be expanded to include a nuclear materials recovery operation, or an area warrant could be judicially granted relaxing both the particularity requirement and the probable cause requirements. The implications of either option are far-reaching. If the emergency exception were expanded, warrantless searches might be permitted in other emergency situations which are potentially less dangerous than a nuclear safeguards breach (i.e., riots, demonstrations). If the particularity and probable cause requirements were relaxed, a constitutional requirement explicitly condemning such searches would be directly contravened. Either option requires a fundamental change in the law of search and seizure which would have a direct impact on civil liberties.

b. Perimeter Searches

Since a thorough perimeter search can lessen the overall onerousness of a recovery operation by allowing time for sensitive radiation detectors
to arrive, such a search is an alternative to an area search without mechanical detectors. It may thus be advisable to plan recovery operations so as to include a perimeter search. Here we presume that the civil liberties impacts of a perimeter search would be less burdensome than those of an immediate area search conducted without radiation detectors designed for such searches. In order to isolate the area in which the stolen material is believed to exist, authorities may have to order a sweeping search of automobiles and pedestrians.

If contraband fissile material were known to be within a certain area (e.g., a city block) a great incentive would exist to search all persons leaving that area. Devices exist for this purpose. Handheld personnel monitors can be used in the same way that handheld magnetometers are used to search persons who activate the portal magnetometer at airports. Their availability and exact sensitivity are classified as secret national security information.

If an emergency were perceived, there might not be time to obtain handheld detection devices. In that case, a "frisk" of all individuals departing from the area suspected of containing contraband material would be necessary.

"Stop and frisk" cases which have appeared before the Supreme Court have held that the authority of a police officer to frisk without a warrant is restricted to a search for weapons which may endanger the officer:

[T]here must be narrowly drawn authority to permit a reasonable search for weapons for the protection of the police officer, where he has reason to believe that he is dealing with an armed and dangerous individual, regardless of whether he has probable cause to arrest the individual for a crime. 97

On the other hand, the Supreme Court has also acknowledged that "The Fourth Amendment does not require police officers to delay in the course of an investigation if to do so would gravely endanger their lives or the lives of others." 98

There is little doubt that the malevolent use of contraband fissile material would "gravely endanger . . . the lives of others." The mere presence of a person in an area known to contain contraband material may serve as the functional equivalent of probable cause for a search. If so, the fact that the person is not in his home and is mobile becomes important. The "emergency" warrant exception can be based on the threat of loss of

96 W. Kunz, Hand-held Personnel and Vehicle Monitor at 246 (report presented to the Institute of Nuclear Materials Management at their annual meeting at Los Alamos Scientific Laboratory, June 18-20, 1975).
97 Terry v. Ohio, 392 U.S. 1, 27 (1968).
evidence: "When there is probable cause to search and it is "impracticable" . . . to get a search warrant, then a warrantless search may be reasonable."99

If the contraband material were known to be within a certain area, it could be contained there only by means of a perimeter search. Radiation detectors could be obtained in the resulting interim period between containment and search. It seems doubtful that the courts would hold a personal search at a perimeter station unreasonable, but they have made it clear that the determination depends heavily on the circumstances of the particular instance.

Case law has indicated that a physical search of pedestrians could be justified by an extraordinary "need to search" in the event of theft or loss of fissile material100 A search administered uniformly to all persons in the controlled area would more likely be held lawful than one conducted arbitrarily. The search would be more acceptable if its scope were restricted, to as great a degree as possible, to the object sought. As an obvious example, a body cavity search would certainly be unreasonable if the material were in a form which must be kept in a container (i.e., Pu100 in the liquid nitrate form which is too large to conceal in a body cavity).

Vehicle searches can be conducted with a mechanical handheld detector.101 The availability of these detectors to authorities conducting the search is extremely important. Technologies for searching for contraband material in vehicles at checkpoints are classified as secret national security information and, therefore, cannot be discussed here.

By and large, the same doctrines applying to personal searches in a perimeter search program would apply to vehicle searches. The Supreme Court has intimated that a search of vehicles constitutes a lesser invasion than a search of someone's home because an automobile may be searched: "where it is not practicable to secure a warrant because the vehicle can be quickly moved out of the locality . . . in which the warrant must be sought."102 Since the need to secure the contraband nuclear material is great and since a perimeter search will ultimately lessen the overall obtrusiveness of the search by providing containment until mechanical detectors can be obtained, vehicle perimeter search techniques seem less likely to be found unreasonable.

As with pedestrian searches, a vehicle perimeter search is an alternative to an area search where there are no mechanical detectors yet available. The exception to the warrant requirement for automobile searches

101 Kunz, supra note 96.
has already been established so that no fundamental change in case law would be required. While this exception would broaden somewhat the already relaxed probable cause requirement for vehicle searches, the civil liberties implications of a search of vehicles exiting from a specific and limited area do not seem terribly significant.

E. Conclusions

If a diversion or theft of fissile nuclear material did occur, it must be assumed that drastic measures would be necessary to locate and recover the contraband material. There is little discussion in the literature of the specifics of such a search since most details remain classified. An operation aimed at recovery would certainly involve at least kilogram quantities of fissile material. Such amounts would probably be easy to conceal in such a way as to shield them from detection over any appreciable distance.

Highly enriched uranium by itself has relatively low gamma and neutron emission levels, making it essentially undetectable if shielded at all. A search for unspiked HEU with radiation detectors would have to include entry into areas normally not subject to searches, and would raise the issue of the warrant requirement. For example, 30 kg of HEU could be successfully hidden from detection by secreting it in a basement sump well under one or two feet of water.\textsuperscript{103} If HEU were spiked with either a gamma or neutron spikant it would be more detectable, but still could be shielded, especially if the perpetrator had taken speedy measures to deposit the contraband HEU in a shielded holding place.

\textsuperscript{28}Th would probably be the most desirable gamma spikant because of its high energy emissions. But gamma spikants suffer from one major drawback. Detectors moving from location to location seeking extraneous gamma radiation will register significant variations in background levels and, therefore, long count intervals and accurate background data must be available. This is a sizable problem since both conditions are difficult to meet, particularly in the context of an expeditious search. In any event, to be detectable for the purposes of location, HEU may require the addition of a very high-energy gamma source, perhaps at lethal spiking levels. Even then, however, effective shielding is certainly possible.

For a neutron spikant, the emission energy is not as important as the rate of emission. Even with a high count rate, concrete or water is a very effective shield. In fact, placing the contraband fissile material at the bottom of a swimming pool or a small lake would make its neutron emissions virtually impossible to detect.

Uranium\textsuperscript{233} reactor fuels contain some U\textsuperscript{235} which will generate radioisotopes producing very high-energy gamma radiation. The high-energy

\textsuperscript{103} This statement can be verified by simple, well-known physical calculations.
emission from $\text{U}^{233}$ fuel will actually approximate lethal spiking, making shielding necessary to prevent lethal exposures. Given that the material must be shielded anyway, it is reasonable to assume that additional shielding will render the contraband $\text{U}^{233}$ undetectable by radiation detectors.

Plutonium emits both gamma radiation and neutrons, each of which is detectable with radiation detectors. Neither is of sufficient strength to allow detection over any distance if simple shielding measures have been taken. Pu could be spiked to enhance gamma or neutron emissions, but in either case simple water or concrete shielding could interdict emissions to render the contraband Pu unobservable at long distances.

Spiking of HEU and Pu could significantly increase the likelihood of locating contraband materials with mechanical devices. $\text{U}^{233}$ is already sufficiently radioactive to make the addition of a spikant superfluous. However, any emissions used for detection could be easily shielded. The search for contraband material would have to be extended into dwellings and, most probably, onto private property. The legal requirement of a search warrant describing with particularity the premises to be searched would be impossible to meet under such circumstances. Responding to an emergency of such potential dimensions as could be created by a theft of fissile material will require not only technological readiness but also some fundamental changes in our current understanding of the law and search and seizure.