Assessment of RDD Event Medical Response, Recovery, and Mitigation
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Purpose of Study and Background

The purpose of this study is to perform an objective assessment of current medical operational capabilities, gaps, and shortfalls pertaining to RDD response in the context of specific representative study parameters (Cs-137, Am-241, and Co-60). Devices such as blood and research irradiators and teletherapy machines containing these radionuclides are considered of greatest relative risk for malevolent acquisition and are in greatest quantity and distribution throughout the U.S. according to the NRC Interim Database (RDD Global Protection Architecture, L. Connell and L. Trost, May 2006). Unlike improvised nuclear devices, RDDs are more likely to result in large-scale medical effects secondary to contamination and psychological effects rather than the widespread death and destruction due to a fission devices (Personal Communication, Dr. Roger Hagengruber, Director, Institute of Public Policy and the Office of Policy, Security, and Technology, University of New Mexico). Although the global threat of nuclear devices is clearly a high priority for our Nation, the ubiquitous nature of sources for RDDs, namely, Cobalt-60, Americium-241, and Cesium-137 are of great national concern due to the lower security measures employed to safeguard, track, and account for these materials, and due to the pervasive commercial and industrial usage.

The persistence of these materials in the environment makes them particularly attractive as weapons of terror. The half-lives of Cesium-137 and Cobalt-60 are thirty years and five years, respectively. Cesium-137 is found throughout the world, and is characterized as an external and internal hazard due to its biogeochemical properties, enabling absorption into the food chain (ICRP, 1979-1988; UNSCEAR, 1969). It is used extensively in blood and research irradiators, but also in gamma radiography and produces beta and gamma irradiation. Cobalt-60 is used in teletherapy devices and research and industrial irradiators, and is both a beta and gamma emitter.

The special case of Americium-241 deserves discussion. Although representing a low-probability event, there is a historical precedent for terrorist use of an Americium-241 RDD, with thirteen individuals having been apprehended in the United Kingdom during August 2004 on Terrorist Act charges: “Conspiracy to commit a public nuisance by use of radioactive materials, toxic gases, chemicals, and/or explosives.” Although Americium is a fissile material, approximately 80 kilograms are needed to produce a bomb; the worldwide production is estimated at a few kilograms, hence making the production of such a device highly unlikely. However, the psychology of possessing such a finished device with the intent of producing mass contamination versus human casualties should not be ignored. (www.cbwinfo.com/radiological/radmat/am241.shtml).

Amerium oxide would be the form of Americium in a RDD. Decay occurs primarily by alpha emission to Neptunium-237 and the half-life is 432 years. Decay products are
detectable as a 59.5 keV gamma and in the urine of exposed individuals. Classic radiation sickness is unlikely except with extremely large total exposure (greater than 1 gram from all routes of exposure). The primary commercially available source of Americium is in smoke detectors (the average home detector contains 1 micro Curie as compared with industrial-use detectors which contain up to 50 micro Curies), and hence more of a concern that Americium may be used as a weapon of terror. Management of individuals exposed to Americium would primarily consist of mechanical decontamination and through use of chelating agents (such as DTPA; Emergency Response Guidebook Number 161, 2004) to prevent binding in bone and liver (primary routes of absorption are through inhalation and ingestion). In summary, threat awareness dictates a low likelihood of Americium use as an RDD to generate large numbers of casualties, however, similar to the other radionuclides previously described, this material could be used quite effectively as a weapon of terror through a misinformation campaign.

Radiological terrorism due to RDDs is generally believed to be easily achievable, pragmatic and inexpensive, requires less technical sophistication, and requires far less source material and lead time for weaponization than is necessary for classical military warfare agents and platforms. The classical military warfare agents are generally recognized as chemical and biological warfare agents, however this definition has recently been expanded more broadly to include a wider spectrum of novel and bioengineered agents such as toxins or genomes coding for specific proteins that induce specific physiologic and toxic effects.

The three main objectives of RDD attacks are: contamination of food/water supplies; area denial; and direct exposure (Len Connell and Lawrence Trost, RDD Global Protection Architecture, May 2006). Extrapolation of these themes leads to additional objectives of inducing fear and uncertainty, and undermining confidence in government. A review of radiological dispersal accidents lessons-learned underscored a major emphasis on the consideration of psychosocial effects in the consequence management, clean-up standards, population relocation guidelines, and anticipatory management (both policy and operational) of such events (Len Connell, Lawrence Trost, Presentation to The DTRA US/Singapore RDD Workshop). Public opinion phone and internet surveys performed by the George H. W. Bush School of Government and Public Service, Texas A&M University, demonstrate public support for enhanced public awareness training and support for additional U.S. government efforts to deter radiological and nuclear terrorism in the homeland. (Sandia Report SAND2006-0753P, March 2006).

As previously indicated, terrorist motivations include relative ease of weaponization, and deployment, and paralysis and fear in the targeted population. These characteristics combined with the high efficacy of RDDs to create a long-term contamination problem further justify the purpose and methodology of this study to understand schisms in medical situation understanding, response and mitigation capability.

Ultimately, recommendations in this study are focused on prevention and countermeasure strategies to minimize casualty generation across all sectors, to include responders, and to minimize environmental impact. Information sources such as technical reference
documents, Subject Matter Expert (SME) interviews, and national U.S. policy and doctrine, form the basis of the assessment.

**Standards of Medical Management**

A comprehensive set of recommendations for population protection was published by the National Council on Radiation Protection and Measurement, and may be found in a report entitled “Management of Terrorist Events Involving Radioactive Material” (NCRP Report No. 138, October 24, 2001). Although some of the material included in this document is clearly outdated, the basic principles remain solid. Differentiation of a RDD event from one due to a conventional weapon is particularly helpful when attempting to characterize the optimum medical response. Similar to other unconventional weapons such as biological agents, consequences of RDD events may be characterized as complex systems, and are not readily predictable or neatly bounded by space and time. Medical consequences such as psychological and physical trauma may occur to persons not wounded by the immediate or localized attack, and the end-effects may be disproportionate to the physical effects. Although the primary zone of psychosocial and external contamination effects will be local, a wider and broader slice of society will be affected over space and time.

Bennett (1999) published a basic synopsis of understanding of responses to risk in *Risk Communication and Public Health* (Bennett, P. and Calman, K., Eds., Oxford University Press, New York). In this document and others, Bennett refers to the involuntary and irrational public response to unfamiliar threats. These threats are described as those posing hidden/irreversible damage, the psychological overlay of “dread” of impending illness or death, and potential special or enhanced dangers to children and pregnant women. RDD and biological agent effects are consistent with this category and reinforce the need for effective pre-event planning at federal, state and local levels, education and training, and supportive technologies to support and mitigate the effects of such events.

Response to any domestic nuclear or radiological accident is generally partitioned into the initial (urgent) and secondary (less urgent) or follow-on phase of the response. Criteria for action are further specified by the International Committee on Radiation Protection and the International Atomic Energy Agency. Although underlying response philosophies may vary, adding complexity to translating raw data from the field into action, generally, high-level medical response activities are straightforward and separated into two primary phases. Response to RDD incidents should be differentiated from more traditional medical responses and associated response criteria due to the potential crime scene element of the event that is geographically separated from the event, and significant psychological overlay (immediate and delayed).

The initial medical response phase to a RDD event includes the immediate emergency management procedures necessary to contain the threat and mitigate further loss or consequences to health, environment or property. Primary tasks involved in the initial phase include: incident command and control to include information flow; intelligence, surveillance, and reconnaissance; search and rescue; fire suppression; casualty triage and
initial management to include hazard mitigation. Primary tasks involved in the second phase of the response include: employment and coordination of Federal assets to include specialized quick response teams from Department of Defense (including National Guard and Defense Threat Reduction Agency assets), Department of Energy/NNSA (Radiological Assistance Program), Department of Homeland Security (FEMA), and FBI. These teams provide additional capability for site surveillance and reconnaissance, and forensics analysis and threat/vulnerability characterization.

The relationships between the aforementioned agencies are evolving, and the intergovernmental coordination is complex, however, these relationships have incrementally improved within the new National Response Plan and National Incident Management System (NIMS) framework. One area in this relationship-building that needs continued emphasis and improvement is information-sharing, particularly between non-medical and medical assets of the response. All too often, these entities do not share a common operational picture and do not have access to relevant, vital information such as threat, actionable intelligence, and vulnerability analysis information that is essential to an optimized response. Advanced information systems and knowledge discovery and dissemination approaches using new data-mining and post-analytic fusion engines can help enormously.

A number of information-sharing initiatives are underway to assist in alleviating problems that have been identified through training and exercises and real-world homeland security and defense operations. The 9/11 (WMD) Commission Report helped to focus resources on information-sharing gaps. One solution includes the establishment of an office responsible for information sharing under the Office of the Secretary of Defense (Ms. Debra Filippi). This office works closely with civilian and military agencies involved in the entire spectrum of homeland security and defense response and recovery. The author of this study was also requested to address the JASONs on this topic, thus indicating significant White House interest. On the operations level, a number of interagency MOUs/MOAs exist to facilitate information-sharing at the national, state, local and regional level. Perhaps most relevant to the operational picture are inter-state emergency management assistance agreements that specify sharing of resources, assets, and underpinning critical information during a homeland security/homeland defense incident. All fifty-four states and territories have implemented inter-state such emergency management assistance agreements.

**Historical Medical Consequence Management Lessons-Learned**

Our global medical experience pertaining to the management of medical consequences of RDD exposure largely stems from experiences in Japan, Chernobyl and Goiania. Jacobs et al. published data on the correlation of white blood cell depression with mortality in 1963 (Military Medicine, 128, 732-739, 1963). Post-Chernobyl, Cesium-137 was determined to be the key residual environmental contaminant (NCRP, SC 64-23, April 1986). The Chernobyl experience documented a total of 134 Acute Radiation Syndrome (ARS) of the total of 400 documented worldwide (V.K. Ivanov, et al. Medical
Radiological Consequences of the Chernobyl Catastrophe in Russia and Consequences of the Chernobyl Catastrophe on Human Health, Nova Science, New York, 1999). The Cesium-137 radiological accident in Goiania, Brazil in 1987 resulted in a total of 249 contaminated patients.

Acute Radiation Syndrome (ARS) comprises the comprehensive set of pre-clinical/clinical and biological effects arising from whole body penetrating radiation exposure. End-organ effects can lead to death within hours or weeks. (NCRP Commentary No.19, 31 December 2005)

There is much to be learned from the clinical experience in Goiania, Brazil. Of the 249 contaminated patients (age range 4 to 38 years), 48 acute radiation syndrome patients were triaged and treated with Prussian Blue (ferric hexacyanoferrate), selected as the agent of choice for enhancing excretion of cesium. This population had a documented exposure of 1-7 Gy (100-700 rad) as indicated by bone marrow suppression and supportive cytogenetic testing. Subsequent statistical analysis yielded a Poisson distribution of cells with chromosomal aberrations. This finding supported the management hypothesis that some patients had received non-uniform exposure to radiation. (The Radiological Accident in Goiania, IAEA, Vienna, 1988; Richmond, CR. Accelerating the Turnover of Internally Deposited Radiocesium. In: Kornberg HA and Norwood WD, Eds. Diagnosis and Treatment of Deposited Radionuclides. Excerpta Media Foundation, Amsterdam, 1983; 315-327.)

Based on these experiences, the range of 10 mGy (1 rad) to 100 mGy (10 rad) has been determined to correlate most strongly with a 1/1000 risk of cancer and observable cytogenetic chromosomal aberrations. As a corollary to this finding, radiosensitivity is directly related to cell turnover rate, and the most sensitive early biological marker is lymphocyte count. Cytogenetic techniques are extremely helpful in determining exposure as stated above. When combined with blood measurements and clinical findings, an accurate picture of radiation exposure can be determined. In summary, observable end-organ effects correlate with radiation dose and other host susceptibility factors. White blood cells/lymphocytes are the most susceptible organ system to RDD exposure and nerve/brain tissue is the most resistant. This information has practical applications in triage. Additional tools in the tool kit are derived from Chernobyl lessons-learned. These aggregate findings form the basis for triage and differential diagnosis by symptoms and blood counts, and the LD/50 guidelines (lethal dose for 50% of the population) of 6.5 Gy (650 rad) with skin injuries and 6-8 Gy (600-800 rad) without skin injuries. This assumes medical care and surge capacity for care.

In summary, Chernobyl and Goiania have taught us much regarding effective triage and management of radiation casualties. To this end, development of rapid triage capability employing biological markers which may be integrated with environmental sensing and plume modeling data would greatly support the first responder end goal of rapid situation awareness/common operational picture generation. To this end, the Chernobyl and Goiania experiences support a multi-modal system for early evaluation and triage of casualties, which may provide additional insight that is useful in development of policy
decisions on allowable radiation exposure in responders and health care workers with repetitive exposure to contamination.

**Current Baseline of Medical Management of RDD events**

A number of myths exist regarding exposure to RDDs. First, it is important to recognize that contamination to a health-endangering level is unlikely in the event of a RDD event. This observation applies to both responders and caregivers. In addition, contamination of responders via ingestion, inhalation and absorption through the skin is also very unlikely. Additionally, similar guidelines will apply to exposure to improvised nuclear devices (INDs).

The initial radiological survey is an essential element of the initial, baseline assessment of exposure to radioactivity and should be performed by health physicists or other similarly trained personnel. The accuracy and timeliness of this assessment is critical to effective consequence management. An integrated, common operating picture employing a distributed, on-site dosimetry monitoring system is highly desirable and represents an effective management tool for consequence management. Such a dosimetric system would map exposures to geolocation and result in a highly accurate and predictive map.

Radiation exposure continues long after the initial event, hence requiring an essential baseline understanding of chronic effects and exposure levels considered as “medical risk” triggering events for protective action. Generally, the “trigger” implies a .5% cancer risk and no acute effects (corresponds to about 0.1 gray or 0.1 sievert, absorbed dose versus protective quantity). (DHS Working Group on RDD Preparedness, May 2003, and personal communication with Dr. Fred Mettler, 2006) This quantitative, science-based approach is much more meaningful than an ALARA approach, although an ALARA approach may endure due to public pressure (see below), since clear-cut medical consequence management and mitigation/preventive actions correspond to dose and anticipated relative hazard and physiologic effects. Although, prevention of exposure is clearly a more viable approach than secondary mitigation and consequence management, guidance for post-exposure medical management is certainly necessary in a tiered approach to medical management. Tiered approach implies layers to management to include time/distance/shielding and targeted treatment of end-organs. Evaluation of Chernobyl workers reinforced this approach, which yielded a dose to the medical staff of approximately 10 mGy or 10 mSv (DHS Working Group on RDD Preparedness, May 2003). Historical data refutes the logic for use of Prussian Blue in RDD incidents, although considered the standard of care in management of patients in Goiania.

Once an understanding of the event and resulting/potential exposures to radioactivity has been achieved, the issues of triage, decontamination, contaminated medical waste disposal, and mortuary affairs are issues that require further attention. First and foremost, treatment of life-threatening injuries supercedes decontamination procedures. However, it is important to recognize that treatment facilities and highly skilled personnel are “renewable resources” and should be considered as such when managing contaminated or partially decontaminated patients. For those ambulatory and minimally-affected
individuals, advance guidance for “sheltering-in-place” and home care is an important adjunct to medical treatment facility based care and should be considered a proactive component of a public, health care provider, and media education campaign.

Revised interdisciplinary training for medical staff which better integrates a balanced, situation-awareness approach to medical management of radiological casualties is needed. Interviews with physician SMEs (see Katona, Kadlec, Gray, and Smock) indicate that retention and time dedicated to maintaining currency with respect to management of these patients is limited and receives limited emphasis in continuing medical education programs. One continued theme is maximizing the efficiency and use of current processes and protocols in disaster management crossing the spectrum of all threats and hazards. For example, more efficient management of triage systems, contingency facilities, hospital discharges of non-critical patients, and specialized equipment mapped to personnel and facility preparedness to handle special incidents. Individual knowledge and leadership is essential to build, implement, and enforce standards and protocols. This knowledge and leadership must transcend across all levels of care providers, pre-hospital to definitive care. Some cities, such as New York, have invested in specialized RDD teams with embedded medical capability that are analogous to military teams described below.

Critical enablers of disaster management are communications, transportation infrastructure, information sharing, and implementation of medical standards of care with operational relevance and pragmatism. These systems and practices must be exercised regularly to ensure inter-facility and inter-agency interoperability and uninterrupted transportation of such items as medical treatment fluids, water (potable and for decontamination), and stockpiled materials. A number of cities have established specialized communications networks for use in disasters (i.e., Readinet in LA County). A number of information sharing systems exist. The Terrorism Early Warning System is one such system used to network first responders, intelligence professionals, and law enforcement during a terrorism event.

Across the spectrum of operations, the concept of health protection incorporating radiation dose limits is one that forms a singular point of significant contention among agencies. For example, the EPA has not endorsed the Nuclear Regulatory Commission’s (NRC) rule for site clean-up and has issued its own (conflicting) guidance. This publicly visible conflict of established standards openly undermines the confidence of the general public and critical sectors of the responder and receiver communities. (Background information on “Ionizing Radiation-Safety Standards For The General Public”, Position statement of the Health Physics Society, reaffirmed March 2001). Specifically relevant to this study is the necessity for a “jumping-off” point from baseline standards, enabling optimized outcomes-based medical management in the setting of an act of radiological terrorism.

The EPA guidance (Comprehensive Environmental Response Compensation and Liability Act [CERCLA or Superfund], Resource Conservation and Recovery Act [RCRA], and Toxic Substances Control Act [TSCA]) is derived from a source constraint
of 0.15 mSv in any year that assumes lifetime cancer risk should not exceed a goal of approximately $10^{-4}$. This premise is in striking contrast to the ICRP (International Commission on Radiological Protection, ICRP Pub. 60, Ann. ICRP 21 (1-3) and NCRP (National Council on Radiation Protection and Measurements, Report No. 116; 1993) recommendations which specify an allowable dose limit and derived reductions in dose based on the ALARA principle. The Health Physics Society opposes the quantification of ALARA and supports its primary use as “…a philosophy for striving for excellence in the practice of health physics” (“Occupational Radiation-Safety Standards and Regulations are Sound: Position Statement of the Health Physics Society,” Mclean, VA, March 2000). In the context of a RDD or other unconventional mass care scenario, it is generally unacceptable to apply criteria like CERCLA or extrapolate guidelines from occupational health and safety derived settings. (Also, see comments from Jarrett below). Historically, in the event of a large accident, they have never gone as low as CERCLA, because it would be impractical.

Military Medical Capability Perspective

Interviews with military medical SMEs included those tasked with supporting and developing procedures for domestically-focused National Guard quick response team leadership (CERF-Ps, CBRNE Enhanced Response Force Packages and CSTs, Civil Support Teams), stressed the need for consistency among modeling and simulation systems. Specifically, predictive analysis of anticipated bio-effects (to include psychological) and contamination (environmental and personnel) due to RDDs in an urban environment is lacking standardization and consistency. The ability to rapidly determine the extent of individual exposure and potential long-term health consequences through a wearable device is viewed as a current gap. Real-time epidemiologic surveillance of contamination needs improvement, and would assist in optimizing outcome, medical responder performance, and mitigate the medical consequences

Regarding the issue of decontamination protocols, current protocols emphasize decontamination in parallel with essential life-saving measures. This process is dynamic, with a recognized need for adaptability and real-time adjustment of priorities, depending upon real-world events. However, current thinking is that facilities will be considered contaminated post-receipt of casualties, and a number of contingency locations will need to be pre-designated. Suggestion of “clean versus dirty facility” pre-designation suggested by Dr. Fred Mettler is viewed as unrealistic by many military medical responders (many of whom work or have worked in civilian medical facilities) from political, business operations, and implementation perspectives.

Civilian First Responder Community Perspective

Prior studies (Musolino and Harper, 2006) have indicated a number of significant concerns voiced by key end-user populations spanning responders and senior policy and decision-makers across government, academic, and private sectors impacting measurable health consequences. The radiological accident in Goiania in 1985 underscored these
themes and also reinforced the importance of radiological source security and regulatory/compliance processes. Goiania emphasized the need for collaborative international databases such as those which currently exist and continue to function as an important element of sharing lessons-learned and mitigation of future loss in accidental or terrorist events.

To further elaborate, these concerns included, but were not limited to:
- triage and evacuation protocols
- indications for sheltering in-place (quarantine and containment)
- facility environmental management
- unambiguous operational “triggers” to initiate and terminate protocols
- sustainable medical management of mass casualty events, triage of the “worried well” and management of post-event or delayed psychological trauma patients.

A number of communities have taken a proactive approach to addressing these concerns. For example, Louisville, Kentucky has established a Joint Emergency Services Unit (ESU) consisting of team members deputized by the U.S. Marshalls and with expertise across multiple domains such as Law Enforcement, Health Care (physicians and nurses), and Health Physics. This unit establishes medical response protocols for a wide range of RDD incidents, conducts regular training with the National Guard Civil Support Teams, (CSTs), shares actionable information with the CSTs, and is highly functional due to being embedded within the emergency response mechanism of the State of Kentucky (Smock and Gray, personal communications). The Joint ESU is authorized to respond to any incident, regardless of local, state, or federal jurisdiction, and is especially prepared to respond when there is a need for law enforcement capability in a hot zone or there is a known or suspected victim/human biological vector. This Unit may serve as a model for other states and regions wishing to build an integrated response capability with a horizontal organizational structure.

The concerns listed continue despite the U.S. EPA 1992 guidelines which clearly enunciate evacuation criteria in the acute explosive RDD scenario. These concerns appear to reflect the greater umbrella of concerns of ambiguity regarding science-based standards for radiation based decisions or “triggers” for allowable radiation exposure. This lack of standardization is partially due to the focus on planning and personal protection to achieve optimal near-term survival (the bar is set at twenty per cent survival for nuclear attacks) and to mitigate other health and environmental near-term consequences.

Unfortunately, a somewhat ambiguous operational medicine strategy has resulted in a less-than optimal approach to population survivability and morbidity. The net health effects from chronic and geographically separated RDD events have been described in NCRP forums (NCRP Symposium on “The Control of Exposure of the Public to Ionizing Radiation in the Event of an Accidental Attack”, Reston, VA, 15 May 1982).
Summary of Subject Matter Expert Observations to Achieve Enhanced Medical Outcomes:

In an effort to achieve a more balanced and effects-based approach to near-, mid-, and long-term medical consequences, the following observations and recommendations have been collated from SMEs:

- **Education and Training**

  DTRA subject matter experts strongly recommend that members of specialized response teams receive focused technical and health physics training. Fred Mettler (39th Annual Meeting of the NCRP; published in Health Physics “Medical Perspective on Ways to Improve Radiation Protection Standards”) summarized the frustration of the medical community at-large by the following statement: “…radiation protection in medicine is not likely to be solved with the addition of more standards but will require a combined approach with the medical and educational communities.” The previously described integrated Joint ESU conducts combined technical, medical management, and health physics training and has begun to address the challenges inherent to integration of new technologies into existing response and medical management protocols. Such strategies should be considered as an important pillar to all-hazards response capability building across the spectrum of threats.

- **Need for implementation of situation-dependent emergency dose and dose-rate guidelines: next-generation ALARA**

  ALARA (as low as reasonably achievable) techniques are viewed by the response community are difficult to interpret and comply with. As a whole, generic parameters are unpredictably responsive to large uncertainties, and do not reflect the most credible assessments of levels of contamination (NCRP Report No. 138). For example, in an urban setting, wind and microclimate conditions may be highly variable and unpredictable, thus adding to the uncertainties of response.

  In addition, the inconsistencies and inappropriateness of equally applying ALARA guidelines to occupational exposure settings and terrorism events has been noted by Mettler (personal communication, July 2006) and cries for operational exposure guidance from the perspective of the incident commander. These inconsistencies may be summarized by differentiating the settings of occupational exposures from accidental or deliberate radiation exposures. The situations demand different personal or force protection methodologies emphasizing what is “correct” for the given situation vice what is “minimal”. In an attempt to address many of these concerns, Dr. Craig Conklin of DHS heads a working group nearing completion to establish ongoing exposure limits across operational response settings.

  In 1991, the International Commission on Radiological Protection (ICRP) referred to the multi-factorial concept of risk as equaling dose X risk factor (per unit dose), with
risk including the variables of age, weight, sex, and dietary habits. The ICRP continued to emphasize that risk must be based on scientific rigor, credible assumptions, appropriate methods, and actionable decisions based on known site contamination parameters.

- Sensors and associated response protocol “triggers” represent an applied technology gap

Current sensor networks and protocols do not effectively test for alpha and beta-emitters in field environments and are not adequately integrated into automated “triggers” for protocols. This observation identifies a large gap in current sensing protocols. A summary of suggested instruments to be considered during the planning for radiological terrorist attacks is collated in the NCRP Report No. 138. This sensor data would merit integration with other data sources previously described to achieve a field-deployable common operational picture.

- Suboptimal integration of the media in RDD medical response, education, and training

The media can be a strong ally for information dissemination and synchronization during a disaster. Federal, state, and local authorities should consider employing the media to assist with self-triage, management of the “worried-well”, and updated evacuation procedures and route usage.

- Inconsistent standards for data analysis, need for unambiguous “triggers” for decision-making and action, and application to field operations

Over the years, policy guidance regarding radiation-based allowable exposure has become increasingly restrictive ((NCRP, 15 May 1982). Although response philosophies may depend on such dose modifying factors as: occupancy factor, geographic distribution (mean maximum dose rates) and time distribution factors, as well as immediate implementation of focused medical management, history has taught that pre-determined, scalable standards-of-care result in optimized effects-based operations, especially in disasters with mass casualties. The basic medical tenets for management and mitigation of radiological casualties still hinge on the cornerstones of time, distance, and shielding (Jarrett, personal communication, 2006). Increasingly restrictive values for data interpretation have resulted in early trigger criteria for intervention and action and have substantial economic and social burdens which negatively influence the establishment of rigorous scientifically-based and standardized criteria. In addition, highly restrictive criteria unrealistically assume an infinite resource of skilled responder and receiver personnel and also do not account for the need to protect and retrieve critical infrastructure.

The bottom-line is ambiguity of medical protocols and response criteria, and the resulting confusion regarding medical standards of care during RDD events. For example, patients at “ground zero” of a RDD event are not “salvageable” and should be considered “non-rescue-able”. In this scenario, precious resources and personnel
should not be deployed and unnecessarily expended or jeopardized (Jarrett, personal communication, 2006). This would depend upon the scenario. GZ may be too contaminated or may not. This underscores the need for fast, accurate surveys of contamination. Adoption of early triage and management criteria which focus on data sources such as biomarkers and environmental data appears to be a scientifically sound and politically robust strategy worthy of consideration. Data models are an integral component of medical decision-making and strategic planning and should be treated as such through integration into the larger “situation awareness” picture. A “train as we respond” approach which includes such information tools within the accreditation and credentialing/continuing education requirements would be integral to improving this process.

Such a comprehensive information management approach would address a number of concerns voiced by SMEs, and would enable first responders and physicians alike to use unambiguous indicators and “triggers” for specific, pre-determined community-wide actions. Although a notional set of solutions was presented in this study, such bio-informatics-based operations will support the end goal of optimized medical management of RDD events.

**Summary and Recommendations**

Globally, the U.S. Department of Energy/National Nuclear Security Administration is viewed as a premier authority on the physical effects, science and technology and weaponization potential of radionuclides to be incorporated into weapons of radiological terror. To this end, medical consequences represent a significant area of national concern that could substantially benefit from the DOE/NNSA leadership role. For example, this leadership naturally ensures close coupling of the scientific understanding of such devices, the potential health and environmental effects, appropriate methodologies for prediction, modeling, simulation, detection, and mitigation. This comprehensive understanding impacts ability to influence public policy on medical consequence management.

This study identified a number of shortcomings and opportunities for initiatives to address these shortcomings. The DOE/NNSA could play a lead role at the national and international levels to address these shortcomings.

The identified shortcomings are as follows:
- Decentralized leadership and chain-of-command;
- Limited public awareness campaign;
- Lack of integrated, standardized modeling and simulation capability;
- Separate sensor and health care databases resulting in lack of unified situation awareness from the field to definitive care facilities;
- Lack of interdisciplinary training;
- Limited international partnership networks focusing on RDD medical management at all levels from public health policy to implementation of care;
- Lack of interoperable sensor platforms;
• Lack of multi-threat countermeasures with focus on common pathways of injury and disease;
• Limited international technical information exchanges.

The potential initiatives to address the identified shortcomings are:
• Champion establishment of a single point-of-contact across government agencies that will serve as the lead in response and preparedness across the spectrum of threats at Federal, State, and Local levels (Conklin);
• Champion the public information and awareness of the global threat of RDDs and individual and community protective measures, and invest in a program which targets the specific needs of health care providers/responders and senior executives. Some high priority topics include: vulnerability of existing safeguard, tracking, and accountability systems of radionuclide sources for such devices and awareness of medical systems/components that employ radionuclides;
• Support integration of existing modeling and simulation capability into a national system for incident and medical consequence management (National Incident Management System); natural locations for this integrated capability include the DHS Homeland Security Operations Center, NORTHCOM, and FEMA operations center. Intelligence fusion centers throughout the United States would benefit from such a common operational picture and associated education and training initiatives;
• Support integration of responder and health care provider (first responder, first receiver and medical treatment facility personnel) detection device data/information into a Common Relevant Operational Picture (CROP) to achieve rapid situation awareness of the medical epidemiology of RDD incidents. Such a system would help achieve appropriate triage, customized, isotope-based management, appropriate resource allocation, and requests for information (RFIs) which are medical outcomes-driven within the scope of a rapidly evolving event or series of events at the local, state, regional, national, and transnational levels. Interagency partners include DoE/NNSA, DoD, DHS and DHHS;
• Champion integrated and collaborative training emphasizing response and preparedness of health physicists, rapid response team members, and health care providers. Such training would optimally promote more comprehensive (environmental, operational, and physiologic/psychological) exposure guidelines emphasizing pragmatic and operationally-relevant standards to include clean-up and aftermath environments. Such guidelines would replace ALARA, would provide operational experience frameworks, and a much-needed tool in the toolkit of health care providers confronted with the patient management challenges due to radiological terrorism;
• Consider a “way-ahead” that builds an international network of partnerships between National Laboratories, strategic DoD educational centers (such as the George C. Marshall Center) and health/public policy academic centers (such as Texas A&M Health Sciences Center and the George Bush School of Government and Public Service); the focus would be promotion of senior executive education and training in CBRNE terrorism and mitigation/prevention of health consequences to include acute and chronic environmental effects; leverage and
expand the use of phone/internet surveys to include medical consequence management of RDD/nuclear terrorism and to track performance metrics of new community-based education and training initiatives (as performed by the George H. W. Bush School of Government and Public Service, Texas A&M University and the University of New Mexico Institute for Public Policy under contract to Sandia National Laboratories);

- Further invest in research and development of field-deployable, portable, interoperable platforms that integrate biomarkers and other minimally invasive physiologic indicators (acute and chronic) of radiation effects. R&D should focus on a broad range of applications of medical decision-making paradigms, to include tactical (intra-operative, triage and decontamination) and strategic (policy for mass decontamination and countermeasures use, population containment, etc.);

- Encourage further R & D of multi-threat responsive, field-deployable radiological countermeasures and pre-treatments that support a CONOP of environmental robustness (for example, implantable or encapsulated system delivery platforms) and protection of perishable human-capital limited personnel assets within the first responder and first receiver communities. For example, little research has been performed near-term in the very promising field of cytokine work relevant to this threat environment (personal communication, COL Dave Jarrett and Roberto Rebeil, Ph.D.);

- Leverage current international programs within DHS and DoD to standardize an events-based information-sharing network; the core focus of this network would be medical consequence management (preparedness and response) of all threats; RDD medical consequence management protocols and training would leverage “lessons-learned” from recent Asia-Pacific regional and country-specific workshops, and would serve as a baseline for technical investment and information exchanges in high priority geographic regions.

**Conversions of Conventional and International System of Dosimetric Equivalents**

The NCRP (1985) supports the use of the International System of Units, in which absorbed dose is given in gray (Gy) and other protection quantities are given in Sievert (Sv). This is in contrast to the U.S. convention of using rad for absorbed dose (1 rad equals 10 mGy), and rem for other protection quantities such as equivalent dose and effective dose (1 rem equals 10 mSv). However, in the context of international terrorism, the use of the newer system would be more useful. For radiation survey instruments, 1 Roentgen equals .01 Gy or .01 Sv. (NCRP Report No. 138, Management of Terrorist Events Involving Radioactive Material, October 24, 2001).
Subject Matter Experts (SMEs) Interviewed


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Acknowledgements

The author of this study would like to acknowledge the National Security Studies Department, Sandia National Laboratories, the DOE/NNSA sponsor of this effort, and the Subject Matter Experts who so kindly provided their time and expertise.

The views and opinions expressed herein do not necessarily state or reflect those of the United States Government, any agency thereof, or any of their contractors.