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Considering Modeling and Simulation of DOD Response to Accidental Nuclear Disaster

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In a post-Fukushima world, defense nuclear disaster planners must recognize and be ready for urgent requests for military support to mitigate the impacts of a civilian nuclear power plant disaster. At both Chernobyl and Fukushima nuclear power plants, explosions, leakage, and paramount concerns of the spread of radiation around the world led to urgent requests for local and international military support to disaster mitigation efforts. A major obstacle to mitigation efforts is the threat to life of operating equipment in high radiation environments. Unmanned systems promise safety for humans through remote operation but risk failure due to radiation damage of electronic and communications components. As live testing of equipment in high radiation environments is impractical, costly, or prohibited, modeling and simulation may identify and better design equipment, optimize operational deployments, and maintain readiness of first responders thereby better preparing the Department of Defense should an accidental nuclear disaster occur in the United States or with one of our allies.

The Department of Defense (DOD) has not responded to scores of past incidents at United States nuclear plants [1-4]. Given the larger scale of Chemical, Biological, Radiological, and Nuclear (CBRN) disasters, the federal government does task the DOD to assist civil authorities in disasters.

"Joint Task Force Civil Support … gains command and control of DOD forces in support of civil authority response operations in order to save lives, prevent further injury, and provide temporary critical support to enable community recovery [5]"

With 135 domestic nuclear reactors [6], as many as 30 additional licenses currently under review [7] and over 500 nuclear reactors operating or under construction worldwide [8], a nuclear disaster with the scale of Fukushima or even Chernobyl may occur that necessitates a response from DOD [5].

Breach of plant defenses against a nuclear disaster at Chernobyl resulted in military intervention, but the military response did not stop nuclear contaminants from spreading across Europe [9,10]. More recently following an earthquake and a subsequent tsunami in March 2011, the Fukushima Dai-Ichi Nuclear Power Plant (NPP) underwent electrical, generator, and subsequent cooling failures that led to partial core meltdowns in boiling water reactors 1-3 [2]. These meltdowns led to large quantities of hydrogen being released resulting in explosions in reactor buildings 1, 3, and 4. The explosions blew most of the roof and walls off leaving debris and releasing further radiation into the atmosphere [11]. Reactor building 4's spent fuel pool (SFP) housed 1535 fuel rod bundles with residual radioactive material that if overheated would lead to much more radiation release than was caused by the meltdowns alone [12]. Responding in depth to the breach in the plant's nuclear disaster containment defenses, manned helicopters attempted to stop spent fuel rod meltdown by dumping water into cooling pools but dump height and cross winds negated the effectiveness of the attempt [13]. Eventually suited manned responders installed pumps, designed for liquid concrete, to feed vast quantities of fresh water into the cooling pools stabilizing the situation [12]. None the less, the breach of the Fukushima Dai-Ichi plant defenses and the slow and often ineffective responses resulted in contamination of a large area of Japan as well as ocean areas with radiation reaching measurable levels in the western United States [14,15].

Given the obvious potential for accidental nuclear disasters in the United States, the U.S. Nuclear Regulatory Commission conducted a systematic and methodical review of U.S. processes and regulations recommending a strengthened defense-in-depth strategy. Strategic objectives addressed "protecting against accidents resulting from natural phenomena, mitigating the consequences of such accidents, and ensuring emergency preparedness" [15]. One disaster scenario, loss of power to cooling pools, is not only applicable to legacy systems like the boiling water nuclear reactors observed at Fukushima, but also to newer designs incorporating passive cooling systems. For example, the AP1000 nuclear reactor design intends to passively remove heat without electrical power for 72 hours, after which its gravity drain water tank must be replenished for as long as cooling is required [16].

As part of the industry's post-Fukushima safety strategy, in 2014 the U.S. nuclear energy industry took a major step to strengthen accidental nuclear disaster defense-in-depth capabilities by adding another layer of public protection with the opening of national response centers at Memphis, TN and Phoenix, AZ, [17]. History indicates operation of response center equipment will be only as effective as the capability of the equipment and the skills and preparation of the operators.

Concern for timely and effective response places a great deal of importance on modeling and simulation to provide a basis for equipment acquisition, operational planning, continuous training, and mission rehearsal of crews [18]. Modeling and simulation of possible response scenarios from these centers to nuclear disasters may better equip the facilities, improve staging and employment operations for such scenarios, and improve the performance of responders. Modeling and simulation of the range of equipment scenarios and responses may contribute to analysis and acquisition of systems suitable for response.

In recognition of their mandate to support the nuclear industry in the event of a disaster, the Department of the Defense has a lot to offer but may not be ready to support in a timely and effective way. Currently the Defense Threat Reduction Agency models and simulates

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many potential nuclear attacks, disaster, and terrorist incidents at a level of security not necessarily appropriate for the open literature [19]. Relying solely on closed research venues may miss significant potential opportunities and miss the creativity found in open markets. Nor do closed venues promote discussion in the open defense modeling and simulation literature. More open discussion within the wider defense community literature about accidental nuclear disaster may generate beneficial outcomes resulting in better public protection.

In terms of equipment, at least as far back as 1997, the Department of Defense recognized the financial benefit of dual purpose use of defense technology for either civilian or defense applications [20]. Unmanned helicopters may perform better and more safely in nuclear disaster mitigation operations than the manned helicopters fruitlessly attempted at Fukushima and Chernobyl [21]. Office of Naval Research Autonomous Aerial Cargo/Utility System, the Army Manned/unmanned Resupply Aerial Lifter or DARPA's VTOL Experimental Plane, and other Department of Defense programs develop unmanned vehicles but they may not have designs suitable for the dual-purpose of nuclear disaster response and mitigation. Potential dual purpose unmanned helicopters include lift-capable K-MAX, Little Bird, unmanned Black Hawk, and Fire Scout. Other potentially dual purpose helicopters include re-configuring for unmanned operations existing lift-capable helicopters such as the Chinook or Super Stallion. If enabled for dual purpose, selected helicopters may be called on in the future to contain or mitigate an accidental nuclear disaster. Beyond aerial platforms, other Department of Defense unmanned systems may also have potential roles in nuclear disaster scenario containment and mitigation. These may include submersibles [22], maritime [23-25] and ground based systems that may "walk" like a person or animal [22,26]. Beyond containment and mitigation, Fukushima recovery operations employed snake-like and transformable semiautonomous robots for inspection and radiation monitoring of the reactor buildings and systems [27]. One recommendation from an operator was to avoid using "emergency robots as stand-alone machines" supporting the dual-purpose notion [27]. Modeling and simulation of dual purpose system capabilities as well as possible equipment modifications may increase the suitability of Department of Defense acquired equipment to serve in nuclear disaster containment, mitigation, and recovery scenarios.

Dual purpose equipment designs may infer additional cost for radiation hardening that program managers may seek to avoid. Department of Defense space system offer high radiation technology that may enable successful dual purposing by informing equipment designs for high radiation environments. Redundancy and alternative path approaches such as a direct link from the UAV to the Control Station as well as an alternative path to a Repeater Satellite to the Control Station are already in use [28]. When designing electrical components that will be used in ionizing-radiation environments one must consider the tolerance of the semi-conductors and ensure they are "hardened" so that their functionality is not hindered by radiation-induced degradation [29]. The Air Force recognized the importance of radiation-hardened avionics recommending that these systems be hardened to a tolerance that can withstand 2270 Rads [30]. Radiation levels within one Fukushima containment building found spikes reaching 4 Sieverts/h (400 Rads/h) [27]. Nearly 4 years later another robot inside the reactor vessel recorded readings up to 9.7 Sieverts per hour (970 Rads/h). The robot used to record this data was estimated to last 10 hours in the radioactive environment but failed in 3 hours [31]. Department of Defense lessons learned through experience as well as modeling and simulation of radiation levels, communications equipment, communications, and equipment survivability may increase suitability and effectiveness of selected dual purpose equipment when deployed in nuclear disaster containment, mitigation, and recovery scenarios.

Advances in simulation interoperability by the Department of Defense reduced stovepipes within the defense modeling and simulation community [32-35]. Contrasting with high levels of interoperability discussion within the defense community, nuclear industry discussion of interoperability training is limited [36,37] between the SCDAP/RELAP5, MAAP, Rascal, and Sandia National Lab's MELCOR simulations that serve the nuclear community [38-40]. DoD-focused Hazard Prediction and Assessment Capability (HPAC) has a past history of interoperability and may be licensed from the Defense Threat Reduction Agency [41]. The Live Virtual Constructive Chemical Biological Radiological Nuclear Explosive Tactical Training System also focuses on tracking individuals and maintaining situational awareness of ground forces within a CBRNE environment [42]. Advancing the level of nuclear modeling and simulation interoperability as described by Tolk et al., [43] with emphasis on training simulations will likely increase the synergy between these simulations thus increasing preparedness of both the nuclear and the defense communities in the event of an accidental nuclear disaster.

The defense community has much to offer that may help contain, mitigate, or recover from accidental nuclear disaster on the scale of Fukushima or Chernobyl if dual purpose design is considered prior to a disaster. Modeling and simulation promises enormous benefits in saving lives, time, and money; for the rare but potentially catastrophic and widespread consequences of accidental nuclear disaster. By way of comparison, destructive testing of unmanned systems in a nuclear disaster scenario is very costly, time consuming, and may be unsuitable due to risk to life caused by radiation. Further, conceptualization, development, analysis, testing, training, and mission rehearsal of unmanned systems through modeling and simulation may be more cost effective while ensuring lives and livelihoods of possibly millions in the future.

One cannot prepare for the countless accidental nuclear disaster scenarios that may arise without proper equipment, plans of operations, and significant training to use the equipment effectively. Due to the severe consequences, researchers and emergency planners must continue to pursue innovative approaches to prepare for accidental nuclear disasters. By using modeling and simulation to help prepare for these disasters we can gain a better understanding of what equipment and methods are successful in different scenarios. This will ensure that operators can properly train with equipment designed for success. Discussion in the wider defense community literature about accidental nuclear disaster planning may advance both equipment, operational planning, and training solutions resulting in better public protection.

References

1. OPA (2013b) "Three Mile Island Accident."
2. TEPCO (2013) "The Development of and Lessons from the Fukushima Daiichi Nuclear Accident."
3. NRC (2014) The Browns Ferry Nuclear Plant Fire of 1975 Knowledge Management Digest. Nuclear Regulatory Commission 16.
4. DOE (2015) Department Of Energy. "Energy Technology Engineering Center Closure Project: The SRE Accident."
5. JTF-CS (2015) Joint Task Force Civil Support. "JTFCS."
6. NRC (2015a) Nuclear Regulatory Commission. Operating Reactors.

7. WNA (2015) World Nuclear Association. Nuclear Power in the World Today, retrieved September 15, 2015.
8. UNSCEAR (2000) United Nations Scientific Committee on the Effects of Atomic Radiation. Exposures and effects of the Chernobyl accident, Vienna.
9. OPA (2013a) “Chernobyl Nuclear Power Plant Accident.”
10. (2012) “The Fukushima Nuclear Accident and Crisis Managament.” Sasakawa Peace Foundation 15-16.
11. (2012) “FUKUSHIMA DAIICHI: ANS Committee Report, Appendix G.”. T. A. N. S. S. C. o. American Nuclear Society.
12. NRC (2012) Nuclear Regulatory Commission. Order Modifying Licenses with Regard to Reliable Spent Fuel Pool Instrumentation. In EA-12-051, edited by Nuclear Regulatory Commission.
13. UNSCEAR (2014) United Nations Scientific Committee on the Effects of Atomic Radiation. Levels and effects of radiation exposure due to the nuclear accident after the 2011 great east-Japan earthquake and tsunami.
14. EPA (2011) “Radiation Monitors Continue to Confirm That No Radiation Levels of Concern Have Reached the United States.” [Press Release]. EPA.
15. Miller C, Cubbage A, Dorman D, Grobe J, Holahan G, et al. (2011) Recommendations for Enhancing Reactor Safety in the 21st Century. Nuclear Regulatory Commission.
16. Bull A (2010) “The AP1000 Nuclear Power Plant - Global Experience and UK Prospects” (presentation). Westinghouse UK (Nuclear Institute).
17. NEI (2014). Nuclear Energy Institute. Nuclear Industry Opens Memphis Response Center to Enhance Plant Safety Nuclear Energy Institute FOR IMMEDIATE RELEASE. NEI.
18. Caro PW (1988) “Flight Training and Simulation.” Academic Press: Human Factors inAviation 229 - 262.
19. DTRA (2015). Defense Threat Reduction Agency.
20. Molas-Gallart J (1997) “Which way to go? Defence technology and the diversity of ‘dualuse’ technology transfer.” Research Policy 26: 367-385.
21. Selinger M (2014) “Unmanned Helicopters Get a Lift.” Unmanned Systems 32: 10-14.
22. Oikawa K (2015) Robot Technology for Nuclear Decommissioning of Fukushima Daiichi NPS. International Research Institute for Nuclear Decommissioning (IRID).
23. Campbell S, Abu-Tair M, Naeem W (2014) “An automatic COLREGs-compliant obstacle avoidance system for an unmanned surface vehicle.” proceedings of the institution Of mechanical engineers part m-journal of engineering for the maritime Environment 228: 108-121.
24. Sharma SK, Sutton R, Motwani A, Annamalai A (2014) “Non-linear control algorithms for an unmanned surface vehicle.” Proceedings of the institution of Mechanical engineers part m-journal of engineering for the maritime Environment 228: 146-155.
25. Svec P, Thakur A, Raboin E, Shah BC, Gupta SK (2014) “Target following with motion prediction for unmanned surface vehicle operating in cluttered environments.” Autonomous Robots 36: 383-405.
26. Hsu J (2014) “the weight of war.” Popular Science 285: 60-65.
27. Guizzo E (2011) “Fukushima Robot Operator Writes Tell-All Blog.” IEEE SPECTRUM.
28. Sullivan-Nightengale D (2015) “Unmanned Aerial Systems: Risks and Opportunities in the Workplace.” Professional Safety 60(3).
29. Srour J, Mcgarrity J (1988) “Radiation Effects on Microelectronics in Space.” Proceedings of the IEEE 76(11).
30. Rayford PP (1981) “Optimal Nuclear Radiation Criteria for Aeronautical Systems.” Directorate of Aircraft Maintenance, Aircraft Engineering Division USAF Engineering Report No. 2-110.
31. Jiji (2015) “The Japan Times: News Report.”
32. Hofer RC, Loper M (1995) “DIS Today.” Proceedings of the IEEE 83: 1124-1137.
33. Schiavone GA, Sureshchandran S, Hardis KC (1997) “Terrain database interoperability issues in training with distributed interactive simulation.” ACM Transactions on Modeling and Computer Simulation 7: 332-367.
34. Dahmann JS, Calvin JO, Weatherly RM (1999) “A REUSABLE ARCHITECTURE for SIMULATIONS.” Communications of the ACM 42: 79-84.
35. Proctor MD, Posey A, Kulonda D (2003) “Why the T in SMART: A Constructive Synergy.” Acquisition Review Quarterly 10: 284-299.
36. With AD, Wakker PH, Slootman LFM (2009) MELCOR/VISOR PWR Desktop Simulator for Accident Analysis and Training. 17th International Conference on Nuclear Engineering, Brussels Belgium, Nuclear Engineering Division.
37. Sanders R, Panfil B (2013) Integration of MELCOR Sever Accident Models. Areva /Corys Thunder Inc: 26.
38. Wang TC, Wang SJ, Teng JT (2005) “Comparison of severe accident results among SCDAP/RELAP5, MAAP, and MELCOR codes.” NUCLEAR TECHNOLOGY 150: 145-152.
39. Moguel LF, Birchley J (2015) “Analysis of the accident in the Fukushima Daiichi nuclear power station Unit 3 with MELCOR_2.1.” Annals of Nuclear Energy 83: 193-215.
40. NRC (2015c) Nuclear Regulatory Commission. “Radiological Assessment System for Consequence AnaLysis (RASCAL) Overview.”
41. Platt N, Kimball WR, Urban JT (2014) “The use of probabilistic plume predictions for the consequence assessment of atmospheric releases of hazardous materials.” International Journal of Environment and Pollution 55: 3-12.
42. NAWCTSD (2014) NAWCTSD Research Project Summaries, USN: 101.
43. Tolk A, Turnista C, Diallo S (2008) “Implied ontological representation within the levels of conceptual interoperability model” Intelligent Decision Technologies 2: 3-19.