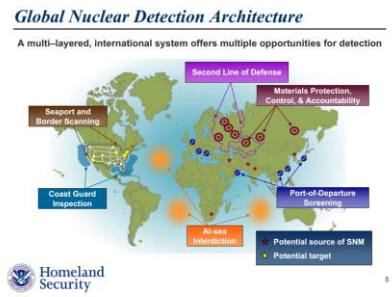
Spatially Layered Defenses Against Terrorism Using Decision and Risk Analysis, Phase II

This project will use advanced risk and decision analysis models to design, analyze, and evaluate counter-terrorism strategies that use multiple layers of defenses, for example in nuclear and radiological detection, border control and in the detection and response to biological attacks. The new models will be applied to improve the design of the GNDA architecture for detection and interdiction of nuclear and radiological materials (see the figure below from DHS). The models will also be generalized to apply to other contexts including layered customs and border protection (CBP) and detection of conventional weapons (IDA).

Project Technical Description



Keywords: Layered defenses, security in depth, Global Nuclear Detection Architecture, terrorism risk analysis, decision analysis

1. **Theme Area:** Risk Analysis
2. **Principal Investigator:** Detlof von Winterfeldt
3. **Institution:** University of Southern California
4. **Co-Investigators:** Henry Willis (funded separately)
5. **Brief Description**

Year 11 will continue a new research effort on modeling and analyzing layered defense systems that the PI started in Year 10[1]. The purpose of this research is to provide guidance to DHS policy makers on how to improve layered defenses. The research was originally motivated by the PI's involvement in a National Academy study on evaluating the effectiveness of the Global Nuclear Detection Architecture (GNDA), a major effort of the Domestic Nuclear Detection Organization (DNDO). The GNDA employs a geographically layered defense strategy to prevent the theft and transportation of radiological and nuclear materials from a foreign source to a target in the US. The GNDA concept of a layered defense is similar to the concept of "defense in depth" promoted by the Nuclear Regulatory Agency for nuclear power plant safety. Layered defenses occur in several DHS contexts, for example, in approaches to catching smugglers (in the foreign country, upon crossing the border, in the US) or in bioterrorism (stopping the production of biological materials, preventing the importation in the US, stopping the distribution and spread of the disease after a biological attack). Modeling layered defense systems will involve extensions of traditional probabilistic risk analysis methods (PRA, exemplified by BTRA and RNTRA) as well as innovations in risk analysis for networks (exemplied, for example, by PEM, DNDO's Probabilistic Effectiveness Model). We will develop and apply these advanced risk analysis models, first for the general case of layered defenses, and then apply them to assessing the effectiveness of features of the GNDA. The generalized models should have applicability for customs and border protection, prevention of biological threats, and interdiction of conventional weapons as well. We have contacted the Defense Science Study Group of the Institute for

[1] Due to another round of FCC reviews, Year 10 was not officially approved until mid-November, 2013 and therefore not much progress can be reported at this point in time (December 6, 2013). Much of the basic material in this White Paper for Year 11 was taken from the Year 10 White Paper.

Defense Analyses to explore the applicability of the layered defense model to the detection and interdiction of conventional weapons.

6. Objectives

The main objective is to improve methods to counter terrorism by using multiple layers of defense ("security in depth"). More specifically, the objectives of Phase I were to a) develop risk analysis methods appropriate to design and evaluate layered defenses; and b) to test these methods in the context of the spatially layered GNDA architecture. In Phase II we will integrate the CREATE model with DHS models (PEM, RNTRA and their successors) and conduct a full-fledged application of the integrated model to a specific case of nuclear terrorism.

7. Interfaces to other CREATE Projects

This research will be closely linked to other work in risk assessment, including projects by Bier, John, Rosoff, Tambe, and Willis. Specific collaborations will be established with Vicki Bier's group, which has studies versions of layered defenses in a game theory context, John's and Rosoff's projects on adaptive adversaries, and Tambe's work on Stackelberg games, Willis's work on bio-surveillance are also related to this effort. We will also coordinate with projects conducted at IDA in the context of conventional weapons detection and interdiction.

The DNDO funded project "Improved DNDO Testing and Evaluation - Decision Analysis and Experimental Design" (PI: von Winterfeldt) is related to this work, but it is concerned with much more specific technical issues of evaluating the performance of detectors and algorithms. In contrast, the proposed project considers the broader question of how to use risk and decision analysis to design and evaluate the global nuclear detection architecture as a whole.

8. Previous or current work relevant to the proposed project

The National Research Council study on metrics for evaluating the effectiveness of the GNDA provided the major motivation for this proposal (NRC, 2013). Of particular relevance to the study of layered defenses is the research by Zhuang and Golalikhani (2011) on defending targets based on geographical proximity or functional similarity, Bier and Haphuriwat's (2011) analysis of joint protection of multiple targets, and Levitin's (2003) research on multi-level protection in parallel systems. Concepts of multi-layered defenses have been built into the DNDO's Radiological and Nuclear Terrorism Risk Analysis (RNTRA) and in its Probabilistic Effectiveness Model (PEM). RTRA is an event tree model with limited capabilities to analyze adaptive responses by the adversary and limited spatial resolution. PEM is a spatial transportation model that determines optimal pathways for an attacker, given perceived defensive detection and interdiction capabilities along different routes and gateways. Research by David Morton and his colleagues (e.g., Nehme and Morton, 2009) on stochastic interdiction in networks is also highly relevant. In addition IDA has worked on layered defenses for detection and interdiction of conventional weapons.

9. Major Products and Customers

This research will: (a) extend past risk analysis efforts by the DHS, CREATE, and others to spatially layered defenses; (b) develop a tool that can be used for both designing and evaluating spatially layered detection and interdiction systems several DHS contexts. The major customers will be DNDO and CBP. Other customers are DHS risk analysts and managers involved in bioterrorism and infrastructure protection. Specifically, the proposed work has grown out of a study by the National Academies study on evaluating the effectiveness of the GNDA. This study was completed in August of 2013 and it was briefed to the DNDO leadership by the committee chair and other committee members in September of 2013. The recommendations included further research and integration of the risk models currently used to support the GNDA. In this briefing, the director of the DNDO and the director's key staff in the architecture office expressed a strong interest and willingness to pursue these recommendations.[2]

10. Technical Approach:

Several past CREATE projects laid the foundation for this effort. In particular, we have adapted project risk analysis tools to analyze the risk of a terrorist attack using radiological materials and we developed and applied defender-attacker decision trees to the evaluation of radiation detection portals. The approach to the layered defense model was previously described in the proposal for Year 10. Assuming a successful development and testing of the model, we will conduct two major tasks in Phase II:

1. Integration of CREATE's Layered Defense Model with existing models at DHS, in particular, PEM and RNTRA (plus the extension currently under development at DHS)
2. Application of the integrated model to a major nuclear terrorism threat.

11. References

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12. Major Milestones and Completion Dates:

- Start – July 1, 2014
- Workshop on integrating RNTRA and PEM with CREATE's model – December 31, 2014
- Full scale application of the model to a nuclear terrorism threat – April 30, 2015
- Publications and dissemination – June 30, 2015

[2] Due to the strict National Academies' Conflict of Interest (COI) rules, I am not allowed to directly contact DNDO staff members to confirm the support for the proposed study until the public release of the Academies' report on December 16, 2013. Once released from my COI, I will establish contact with Huban Gowadia (Director, DNDO) and Frank Szabo (Assistant Director, Architecture). Based on the meetings with them in September, 2013, I have no doubt that they will be interested and supportive.

13. Biographical Sketch

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Detlof von Winterfeldt is a Professor of Industrial and Systems Engineering and a Professor of Public Policy and Management at the University of Southern California. From 2009 to 2011 he was on leave of absence from USC as Director of the International Institute for Applied Systems Analysis (IIASA) in Vienna, Austria. Concurrently with his term at IIASA, he was a Centennial Professor of Operational Research at the London School of Economics and Political Science. In 2003 he co-founded the National Center for Risk and Economic Analysis of Terrorism Events (CREATE), the first university-based center of excellence funded by the US Department of Homeland Security, serving as CREATE's director until 2008. For the past forty years, he has been active in teaching, research, management, and consulting. He has taught courses in statistics, decision analysis, risk analysis, systems analysis, research design, and behavioral decision research. His research interests are in the foundation and practice of decision and risk analysis as applied to the areas of technology development, environmental risks, natural hazards and terrorism. He is the co-author of two books, two edited volumes, and author or co-author of over 120 journal articles and book chapters on these topics. As a consultant he has applied decision and risk analysis to many management problems of government and private industry. He has served on eighteen committees and panels of the U.S. National Academies and the U.S. National Science Foundation, including an appointment to the National Academies' Board on Mathematical Sciences and their Applications. He is an elected Fellow of the Institute for Operations Research and the Management Sciences (INFORMS) and of the Society for Risk Analysis. In 2000 he received the Ramsey Medal for distinguished contributions to decision analysis from the Decision Analysis Society of INFORMS. In 2009 he received the Gold Medal from the International Society for Multicriteria Decision Making for advancing the field. In 2012 he received the distinguished achievement award of the Society for Risk Analysis.

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