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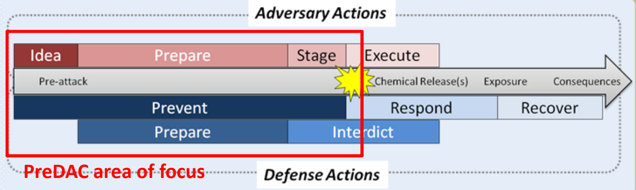
PreDAC: An Interface for Chemical Threat Prediction and Mitigation

Andrew Smith (amsmit@sandia.gov), *Scalable Modeling and Analysis Group*, Sandia National Laboratories
Trisha Hoette, *Center for Homeland Security and Defense Systems,* Sandia National Laboratories

Introduction

The Chemical Threat Prediction and Mitigation Decision Analysis Capability (PreDAC) is a complex, adaptive multi-agent system model that helps predict how terrorists will respond to changes in defensive strategy. We have added a predictive layer to an existing event hazard toolset, the Facilities Weapons of Mass Destruction Decision Analysis Capability (FacDAC). This allows for a multi-resolution simulation of chemical attacks from threat prediction through recovery.



Model Properties

PreDAC is a multi-agent system that is comprised of 3 types of agents:

- Airport agents
- Terrorist agents
- Media agents

Each agent is autonomous, but influenced by the media agents. Each agent, besides the media, acts to maximize their utility which is dependent on their properties.

Media Agents

Media agents are responsible for disseminating information amongst the agents. In Figure 1, the media is public (i.e., all agents subscribe to the same information). Media agents could also be private or represent intelligence agencies. The current implementation of media agents are user controlled – the user of PreDAC will choose which media to inject into the simulation. The available media terms can be seen as information nodes in the other agents' belief networks.

Airport Agents (AA)

An AA's *primary goal* is to protect its population. Its *secondary goal* is to prevent events that may cause a loss in future population (i.e., passengers scared of flying). Table 1 shows the defense systems available for an AA to minimize loss.

	Defense
D1	Vapor/aerosol detectors in terminal
D2	Physical security (guards and gates)
D3	Chem. detection at checkpoints
D4	Ventilation/filtration/exhaust systems
D5	Response readiness

Table 1 *Defenses available to airport agents.*

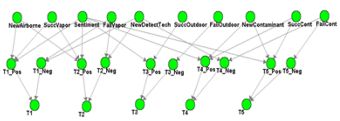


Figure 2 *Airport agent belief network.*

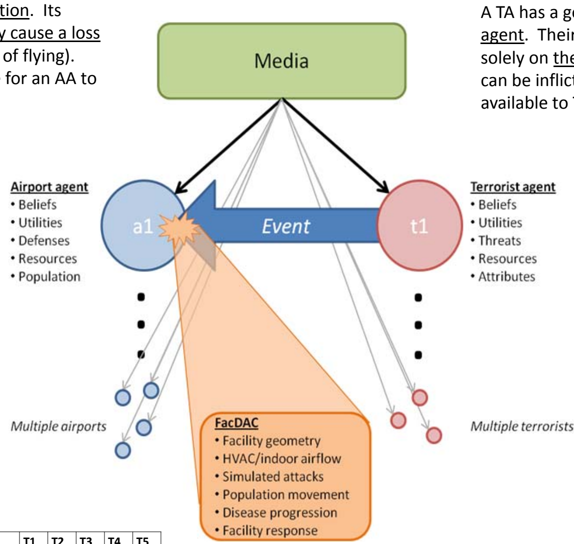


Figure 1 Overview of PreDAC

Terrorist Agents (TA)

A TA has a generic goal to inflict harm on a chosen airport agent. Their *primary goal* and target choice depends solely on the terrorist agent's personality attributes. Harm can be inflicted by means of *fear* or *damage*. The attacks available to TAs are shown in Table 2.

	Threats
T1	Vapor/aerosol release in terminal
T2	Vapor/aerosol in ventilation system
T3	Outdoor aerial release of chemical
T4	Agent spread on surfaces
T5	Food/water contamination

Table 2 *Attacks (threats) available to terrorist agents.*

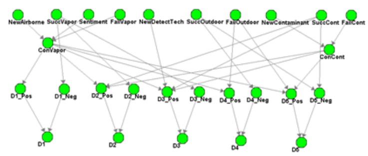


Figure 3 *Terrorist agent belief network.*

Utility Calculation

AAs use *belief networks* to determine how likely a threat is. The sum of these probabilities, along with the probability of the attack's success (determined by the *effect matrix*), cost of a passenger's life, airport population, passenger inconvenience, and the progressive loss function (PrLF, which determines how long the effects of an attack last) provide the utility of a given defense. The maximum utility and its corresponding defense is used as the AA's policy, assuming the airport has enough resources.

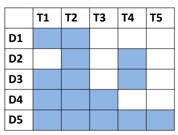


Table 2 *Effect matrix.*

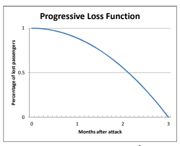


Figure 4 *Example PrLF:* $-\frac{1}{9}x^2 + 1$

FacDAC

FacDAC is a model developed at Sandia used to simulate responses to chemical releases inside a facility (such as an airport). Scenario modeling in FacDAC allows the user to calculate the baseline consequences and potential mitigation provided by defensive measures in an indoor chemical hazard incident. Event parameters calculated in PreDAC will be used to configure the simulation in FacDAC. Once a FacDAC simulation is complete, its output will be used as the result of the event in PreDAC.

Utility Calculation

TAs use *belief networks* and the *effect matrix* in a similar way as the AAs, except that the beliefs correspond to airport defenses. A TA's utility is based primarily on its personality, defined by the following attributes:

- *Profile*: determines the preferred target size.
- *Goal*: either to invoke fear or damage.
- *Capture cost*: significance of not being captured.

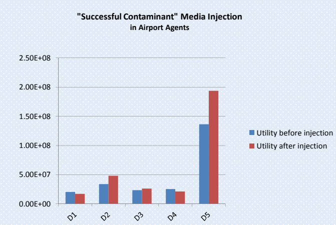
Each attack has specified attributes that cater to various personalities. For instance, **T1** would most likely invoke more fear than damage (since it is potentially easily detectable).

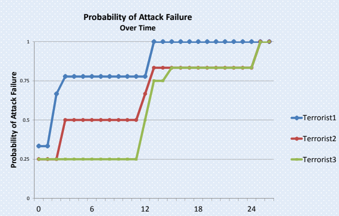
Results

Using 2009 passenger data for 3 US airports (OAK, SFO and LAX), we designed several simulations with varying TA attributes and resources. Our initial results show intuitive updates in the beliefs and utilities of all agents.

We show the utility update in an airport after a "Successful Contaminant" media inject as an example. The utility of **D2**, **D3**, and **D5** increase, while the others decrease. This is intuitive because the "SuccCont" node in the AAs' belief network affects their belief in **T4 and T5**. In the effect matrix, **D2, D3,** and **D5** protect against these threats.

Our results also show that, over time, with various injects, the AAs eventually completely cover all threats. The *Probability of Attack Failure* graph illustrates this. TAs are not yet learning agents – they do not adapt to failure, but this is future work.





Future Work

"Predicting" how adversaries assess various security scenarios remains a hard task. Our goal is to provide an analysis tool which reflects the dynamics of chemical terrorism system in order to develop a flexible and adaptable approach to chemical defense. The extensions we anticipate in the future are:

- *Integrate learning agents for more practical scenarios*
- *Support for game theoretic approaches*
- *Adaptable belief network to support a larger amount of media concepts*
- *Ability to integrate text analysis tools in order to simulate past and/or future world events based on real-life media*

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