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PLANNING FOR TERRORIST-CAUSED EMERGENCIES

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ABSTRACT

This paper provides a framework for assessing hypothesized/simulated emergencies in order to provide quick protection for the populace and infrastructure; and also to protect first responders. These challenges – the need to respond quickly and safely – are the focus for how we must sense, represent, and act upon these progressively revealed events. And this must be done continually. In general, hypergame theory (Vane 2000) provides an approach to pre-planning, situational discovery and model updating to help friendly leadership to decide what to do next in any adversarial scenario.

1 INTRODUCTION

While it is incumbent on civilizations to handle fires, automobile accidents, building collapses, and train derailments; since the Oklahoma City bombing we must also be able to handle terrorist attacks on civilian infrastructure. Planning, which can use simulation results, needs to be done in anticipation of a variety of types of threats and attacks. Once an attack occurs, then dynamic planning needs to be done to cope with the immediate threat, as well as possible additional threats.

Hypergame theory provides a tool for doing both types of planning. It may be applied to evaluating possibilities that are based on suspected terrorist capabilities and intent. These may be derived before the actual emergency to uncover key features of terrorist instigated events in the interest of saving lives. The cost is preplanning, and the primary aid to first responders is provided by real-time retrieval of these scenarios during terrorist-caused emergencies (TCE). This paper will concentrate on the knowledge elicitation and representation of these situations for planning purposes, and will address an information retrieval approach in the last paragraph of this paper.

Furthermore, while many of these attacks to date in the US are one-time strike and run-away events; there are several categories of ambush that would complicate first response. These are addressed in this article and may be captured in successive hypergames, represented in hypergame normal form (HNF). For illustrative purposes, a concrete example is employed to explain the technique. The scenario posits a fire in a mall during Saturday night started by several terrorists who will ambush first responders and non-combatants with assault rifles and a delayed suicide bomber who would cover their egress by discouraging pursuit. Other versions of this scenario will have to be discovered during the emergency.

First Responders are both sensors and fixers during emergencies. These are important aspects of this scenario and the importance of communicating during such events can not be overstated. Most of us are concerned with the dangers associated with fixing a problem such as putting out a fire, thwarting a bank robbery, or repairing a downed power line. Only recently have we begun to realize the danger of feeding first responders into a kill zone.

2 BACKGROUND

Hypergame theory is an extension of the work by Peter G. Bennett (Bennett and Dando 1979, Bennett and Huxham 1982). It is used to reason on two or more perspectives of an adversarial or competitive situation. Its strength is that both enemy capability and possible intent can be recorded in a parsimonious notation called the Hypergame Normal Form. It is designed to hypothesize what information the enemy has, what the enemy thinks about different outcomes, and what the enemy may choose to do.

An explanation of hypergame normal form will be built up in three stages:

- Suspected capabilities - a game theoretic understanding of enemy and friendly capabilities and estimated outcomes in a table,
- Situational beliefs - a series of possible enemy mindsets, and
- Current belief - a single weighting of the situational beliefs.

An explanation of how to use this approach to choose what to do is provided in the discussion section, which addresses uncertainty and the efficiency/robustness of plans.

2.1 Suspected Capabilities (and Their Outcomes)

By setting up a table (Figure 1) of five friendly response options and four enemy tactics, we can begin to explore the ramifications of the decision space. Please accept two apologies from the author: (1) the entries in this table may seem callous and perfunctory, and (2) the entries are made without deep domain knowledge and the expert may find them to be very different from experience. The mall fire is ignited by means of incendiaries and accelerants.

By replacing actual outcomes from Figure 1 with corresponding utility values on a one-to-one basis, Figure 2 is used for all future evaluations. Any non-integer value can actually be used to nuance the differences in the outcomes, for example -4.2 can indicate a slightly worse result than -4. Every entry in this table is negative and represents some damage to either our infrastructure or people with no accompanying advantage for us. The range extends from positive five down to negative five. For example, FFQ means that firefighters race right to the blaze which yields the best results in a benign situation, but terrible results otherwise.

Figure 2 shows a starting point for expert planners. The values for outcomes may be modified for any real world problem, adding more options for friendly forces should add rows to the table, and accounting for another enemy tactic may require adding a column.

2.2 Situational Beliefs (and Assessed Likelihoods)

Figure 3 represents an estimate of how a context label would result in a probabilistic expectation. These are notional probabilities, so a row must add to 1.0. For instance, a clandestine cell might act to set fires, but only occasionally actually shoot at first responders – if they thought they could get away. Whereas, a lone actor would likely start a fire and might also set off a bomb.

In the Figure 3, “Fire + A” represents it with ambush only, and “Fire + B” includes a bomber in addition. The idea is that multiple contexts for terrorists are being considered by the planner: the first two are for one person and the last three concern about four people – labeled a cell. A clandestine cell wants to remain hidden, a combat cell is willing to fight and run – similar to insurgents, and a desperate cell feels that they are about to be discovered.

Outcomes	Enemy Tactics			
Friendly Response Options	Mall Fire with accelerant	Mall Fire with enemy ambush	Mall Fire with bomber	Mall Fire with both
FF Quickly (FFQ)	Fire put out	Fire rages 3D 6 FF casualties 6 Civ casualties	Fire rages 3D 4 FF casualties 10 Civ casualties 1 enemy KIA	Fire rages 3D 6 FF casualties 12 Civ casualties 1 enemy KIA
FF Cautiously (FFC)	Fire rages, triple damage (3D)	Fire rages 3D 3 FF casualties, 6 Civ casualties	Fire rages 3D 1 FF casualties, 10 Civ casualties 1 enemy KIA	Fire rages 3D 3 FF casualties, 12 Civ casualties 1 enemy KIA
FFQ w/ Police	Fire Put Out, EC* EC = Extra cost	Fire rages 3D+ 1 FF casualties 2 Civ casualties 2 Pol casualties	Fire rages 3D+ 1 FF casualties 8 Civ casualties 1 Pol casualties 1 enemy KIA	Fire rages 3D+ 1 FF casualties 2 Civ casualties 2 Pol casualties 1 enemy KIA
FFC w/ Police	Fire rages 3D EC	Fire rages 3D+ 6 Civ casualties 1 Pol casualty 1 enemy WIA	Fire rages 3D+ 8 Civ casualties 1 enemy KIA	Fire rages 3D+ 8 Civ casualties 1 Pol casualty 1 enemy KIA 1 enemy WIA
FFC w/ Police and SWAT	Fire rages 3D EC SWAT costs	Fire rages 3D++ 6 Civ casualties 1 Pol casualty 1 enemy KIA 1 enemy WIA	Fire rages 3D++ 5 Civ casualties 1 Pol casualty 1 enemy KIA	Fire rages 3D++ 6 Civ casualties 1 Pol casualty 1 enemy KIA 1 enemy WIA

Figure 1: Terrorist-Caused Emergency Outcomes (TCE)

Legend: FFx = firefighters and several police,
x = Q for Quick or C for Cautious
FFx + P means significant police (+25 or more)
FFC ++ means with SWAT

	Fire	Fire + A	Fire + B	Fire ++
FFQ	-1	-5	-5	-5
FFC	-2	-3	-3	-4
FFQ + P	-2	-3	-4	-4
FFC + P	-2	-3	-3	-3
FFC ++	-2	-3	-2	-3

Figure 2: Utility Table for TCE Outcomes

	Fire	Fire + A	Fire + B	Fire ++
Lone Actor	.8	0	.2	0
Bomber	.1	0	.9	0
Clandestine Cell	.9	.1	.0	0
Combat Cell	.2	.7	.05	.05
Desperate Cell	0	.1	.5	.4

Figure 3. Situational Beliefs

2.3 Current Belief (Assessed Initially during Planning, Later Updated)

Current belief is the part of the assessment that gets dynamically updated as evidence accrues in real-time during an emergency. Current belief assumes some aspects of reasoning done prior to the event but is based primarily on indicators received after a real fire (event) has occurred.

Figure 4 incorporates the evidence from law enforcement and the Department of Homeland Security (DHS) that is factored into the regional assessment. In the methodology this is also a probability vector (sums to 1.0) and may be updated by any mechanism that makes sense to the planner. This is why the communications from the first responders can make a big difference.

.6	Lone Actor
.1	Bomber
.2	Clandestine Cell
.1	Combat Cell
0	Desperate Cell
0	*Unspecified*

Figure 4: Current Beliefs

The thinking behind the last two entries (desperate cell and unspecified) warrant some further explanation. Current belief is that no law enforcement organization is closing in on a cell in the neighborhood (tending to make it a desperate cell). If such were occurring then the advantage of sharing this information with the first responders would update current belief. The informed first responders could be on the lookout in case the enemy are flushed out, and can increase the probability for reasoning purposes. The unspecified cell is retained for tactical cleverness by an enemy. This is a standard procedure in Department of Defense planning. This means that the enemy might choose to do any of their available tactics and is used when the planner is very uncertain. In our example this would always result in "Fire++" which is more determined by resources than as a tactical choice: do they have more than three people, is one willing to be a bomber, and will the others fight?

The hypergame is shown in Figure 5 and includes Summary Belief entries that have not been discussed before. It combines all three aspects of a hypergame into one figure or table. This summary belief is:

$$C_{\Sigma j} = \sum_{k=0}^{K} CB_k \cdot SB_{kj},$$

where $C_{\Sigma j}$ is the summary belief (expressed as a probability) of column *j* being chosen by the enemy for all *K* enemy situations (and unspecified = 0). CB_k is the current belief for situation *k* and SB_k is the situational belief for each column *j* (probability vector).

Current Belief	Summary Belief (C_Σ)	.69	.09	.215	.005
.6	Lone Actor	.8	0	.2	0
.1	Bomber	.1	0	.9	0
.2	Cland. Cell	.9	.1	.0	0
.1	Cbt Cell	.2	.7	.05	.05
0	Desp. Cell	0	.1	.5	.4
0	Unspecified	0	0	0	1
		Fire	Fire + A	Fire + B	Fire ++
	FFQ	-1	-5	-5	-5
	FFC	-2	-3	-3	-4
	FFQ + P	-2	-3	-4	-4
	FFC + P	-2	-3	-3	-3
	FFC ++	-2	-3	-2	-3

Figure 5: Hypergame Normal Form

3 DISCUSSION

Armed with the hypergame normal form, an Expected Value (EV) can be computed for each friendly response option according to our model. This is recorded in the lower left corner of Figure 6.

The formulation is:

$$EV_i = \sum_{j=1}^{n} C_{\Sigma j} \cdot u_{ij},$$

where $C_{\Sigma j}$ is entry *j* of the summary belief (expressed as a probability) for all utility entries, u_{ij} for option *i*.

Current Belief	Summary Belief (C_Σ)	.69	.09	.215	.005
.6	Lone Actor	.8	0	.2	0
.1	Bomber	.1	0	.9	0
.2	Cland. Cell	.9	.1	.0	0
.1	Cbt Cell	.2	.7	.05	.05
0	Desp. Cell	0	.1	.5	.4
0	Unspecified	0	0	0	1
Current EV		Fire	Fire + A	Fire + B	Fire ++
-2.24	FFQ	-1	-5	-5	-5
-2.315	FFC	-2	-3	-3	-4
-2.53	FFQ + P	-2	-3	-4	-4
-2.31	FFC + P	-2	-3	-3	-3
-2.095	FFC ++	-2	-3	-2	-3

Figure 6: HNF with Expected Values

The EV for each option anticipates the weighted value of friendly response packages, called options. These values combine prior estimates with dynamic revisions of belief associated with current belief. The rational choice is to choose the highest valued option, which appears to be FFC ++, Cautious Firefighters with Police and SWAT team reinforcements. This is an expensive option, so planners need to understand how dependent the recommendation is on the assumptions.

3.1 Uncertainty

The rest of this section is used to explore the example hypergame's mechanism for accounting for uncertainty. The embedded outcomes (suspected capabilities) show that FFC++ is rated as two times worse (-2) for the first responders than FFQ (-1), *when there are no enemy around*. So this recommendation primarily seeks to offset the terrible effects of ambushing first responders and associated additional casualties.

No matter what the planner estimates, our probability estimates do not come from knowing everything in advance that might happen and why. Thus, the planner must not rely solely on such estimates, but instead be willing to update beliefs as new evidence is provided. Simple attempts at optimization are likely to be brittle and subject to outthinking. This is a severe problem for the field of decision analysis that is becoming better documented in these uncertain times. Uncertainty and associated risk actually come from a lack of knowledge, or *ignorance* of causal factors that are only approximated by the planner's experience. Thus the expected values need to account for this uncertainty.

Hypergame theory addresses this concept in an adversarial scenario by realizing that the planner is trying to perform better than the worst case result for the selected option. Each row (option) has a lowest value which is its worst case. The estimation process for the expected value is trying to choose the "best option", and this plot shows any sensitivity because of worst case considerations

In the case of FFQ there is a major difference because of the vulnerability of unsupported firefighters (worst case is -5). An example of solving the HNF for the scenario is shown in figure 7. FFC++ remains superior throughout.

A measure of effectiveness called hypergame expected utility (HEU), is proposed to address such issues. HEU for any option is calculated:

$$HEU_i = (1-g)\cdot EV_i + g\cdot WC_i,$$

where each option *i*'s expected value (EV) and worst case (WC) are combined over the range [0,1] with uncertainty as *g*. Complete uncertainty (g = 1) yields the worst case.

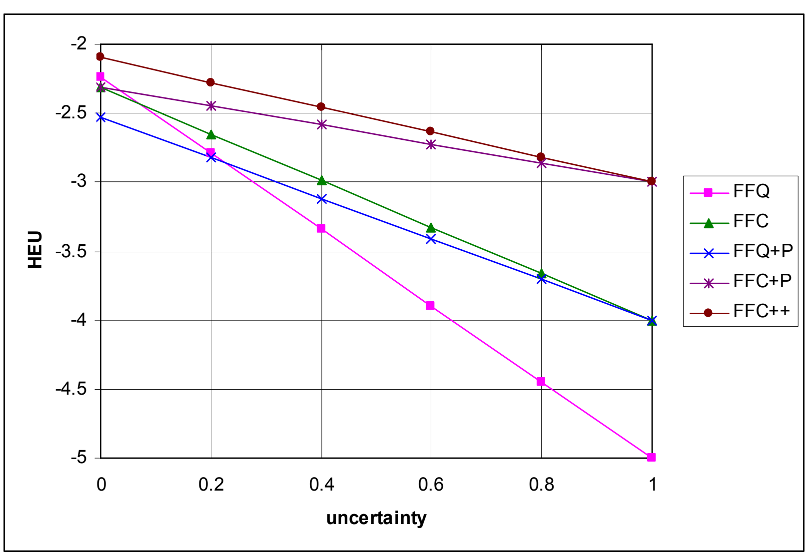

Figure 7: HEU with Robustness Assessment

3.2 Robustness

Furthermore FFQ is a brittle option, with little backup and redundancy. Each friendly option has an associated sequence of steps and dependencies that influence its robustness when performed. This introduces two kinds of refinement that often satisfies the intuition, they are: confidence in the estimate and the robustness of the competing friendly options. Brittle options that require several or many things to be coordinated and done well may result in a high payoff, but they are more subject to failure. Robust options, on the other hand, have an inherent multiplicity of ways that they may be accomplished for equal effect. Robust plans can usually be described as being able to do A *or* B *or* C to accomplish the mission. This changes the robustness weighting function over uncertainty, $r_p(g)$ as per Figure 8.

	g	0	.2	.4	.6	.8	1.0
robust	$r_1(g)$	0	.04	.16	.36	.64	1.0
neither	$r_0(g)$	0	.2	.4	.6	.8	1.0
brittle	$r_{-1}(g)$	0	.36	.64	.84	.96	1.0

Figure 8. First-Order Robustness Function, $r_p(g)$

The options can be ranked from most brittle to most robust as: FFQ, FFQ+P, FFC, FFC+P, and FFC++. Although this makes no difference in the scenario, the planner would have to be very confident to select FFQ. Please note the gentle sloping of FFC+P and FFC++. A modified HEU is computed to represent these differences in Figure 9.

$HEU_i = (1 - r_p(g)) \cdot EV_i + r_p(g) \cdot WC_i$, where each option *i*'s expected value (EV) and worst case (WC) are curvilinearly combined using robustness r_p combined over the range [0,1] representing uncertainty as *g*.

3.3 Sensor Updates

However, FFC++ remains an expensive option. Perhaps the planner can invent a different option, one in which remote sensors can be used to increase the first response commander's confidence that an ambush would not occur. This affects the entire hypergame, but particularly it increases the belief that an ambush of first responders will not occur. By increasing confidence and changing the basic assessment about the nature of the fire, FFQ w/Sensors does become useful as per Figure 10. If unable to contact the mall guards, then revert to FFC++.

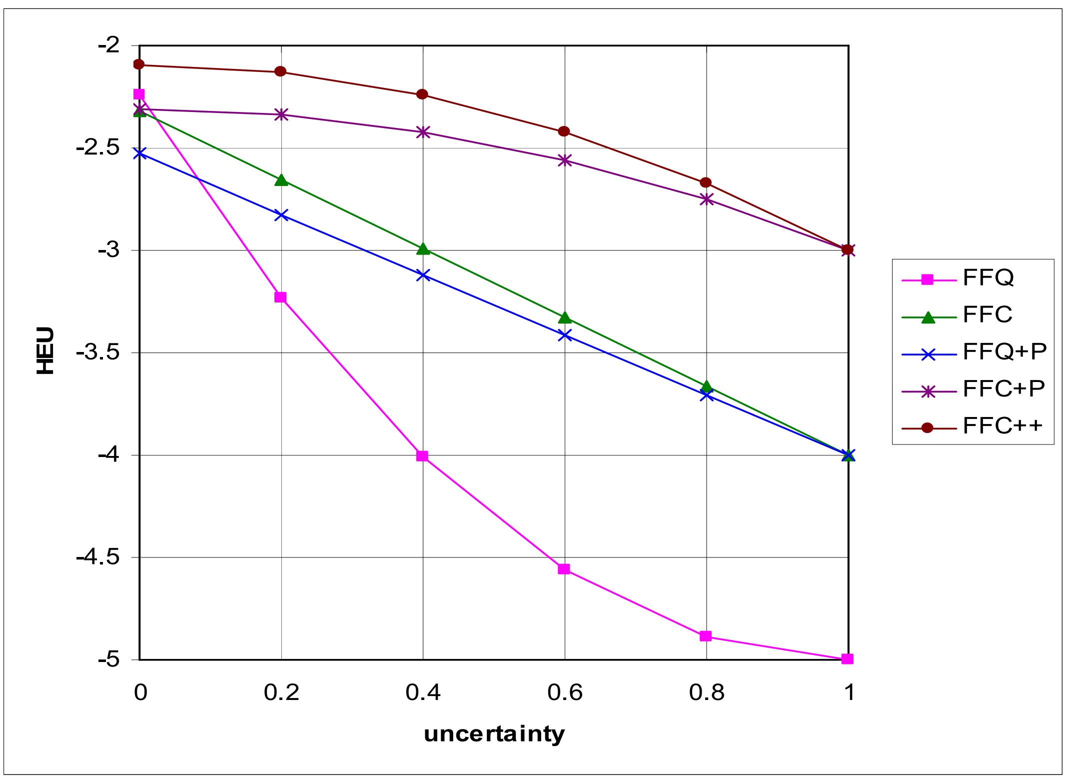

Figure 9. HEU with Robustness

Current Belief	Summary Belief (C_Σ)	0.755	0.01	0.2345	0.0005
0.9	Lone Actor	0.8	0	0.2	0
0.06	Bomber	0.1	0	0.9	0
0.03	Cland. Cell	0.9	0.1	0	0
0.01	Cbt Cell	0.2	0.7	0.05	0.05
0	Desp. Cell	0	0.1	0.5	0.4
0	Unspecified	0	0	0	1
Current EV		Fire	Fire + A	Fire + B	Fire ++
-1.98	FFQ	-1	-5	-5	-5
-2.2455	FFC	-2	-3	-3	-4
-2.48	FFQ + P	-2	-3	-4	-4
-2.245	FFC + P	-2	-3	-3	-3
-2.0105	FFC ++	-2	-3	-2	-3

Figure 10. HNF, Mall Guards + Cameras

This also effectively makes the decision a two stage game, allowing for looking before committing. It is important to show that the HEU plot against uncertainty still favors FFC++ unless the first response commander is very sure as shown in Figure 11.

4 FINDINGS

Simulations can be used to explore emergent properties of the anticipated scenarios. Simulations/modeling can inform the planning experts and simulation outcomes can substitute for some of the original outcomes in Figure 1. They may be incorporated to explore the range of outcomes involving different intensities in fires to inform first responders beyond possible terrorist tactics. If critical rates of fire demand different actions then new columns and rows should be added to the example.

Combat experience teaches that it is prudent not to rush straight towards an emergency. If possible, preplanning several approaches to an affected area makes sense to reduce vulnerabilities. Military analysts have long recognized that bunches of people make easy targets.

Everyone who thinks about the topics addressed in this article receives a blessing that increases their possible recognition of clues to rapidly assess a terrorist-caused emergency. It has long-been observed that preplanning is a fruitful exercise. It improves those involved in the planning. We have used our brains to think/experience a hypothetical situation that may save other lives. Placing the results of such planning in a hypergame supports real-time assessment and promotes timely changes in strategy, as well as tactics.

The breakdown between classical game theory and hypergame theory is that game theory counts on a very explicit axiom that is violated in real life: the requirement for consistent alignment of beliefs between opponents.

While hypergame theory may use two-player, zero sum game theory (sometimes) as a way to determine one or more of the situational beliefs (see the paragraph on 'unspecified" above), it is actually an approach to *recognizing the differences and exploiting them*. In other scenarios than this example, it is used to trap opponents, encourage their mistakes and generally for out thinking the opponent. But this is never accomplished by assuming away the scenario's uncertainty.

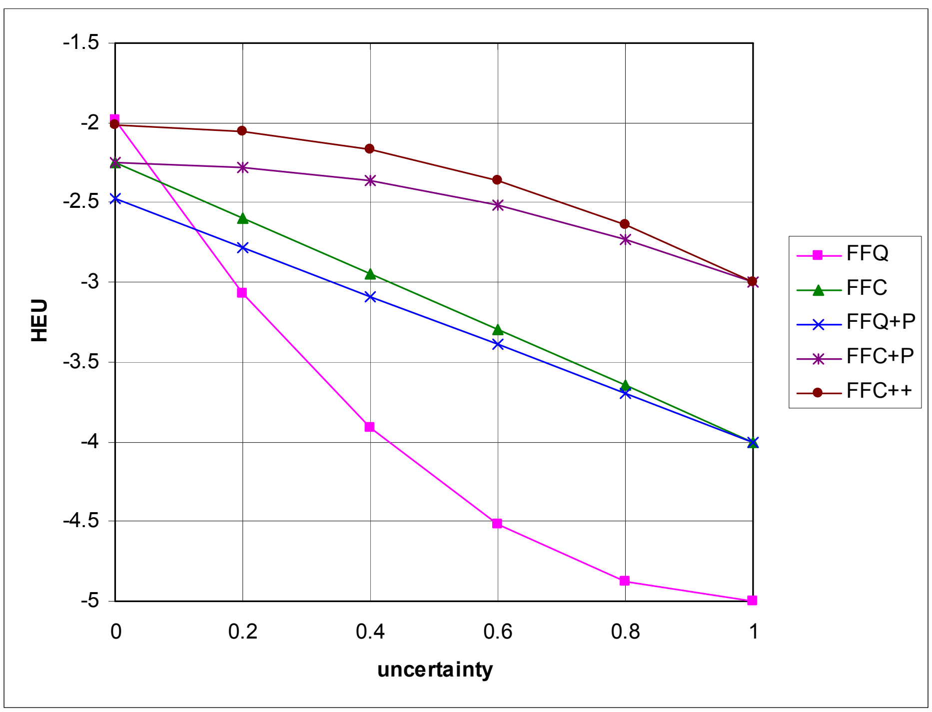

Figure 11. HEU with Mall Sensors Reporting

5 CONCLUSIONS

The theoretical advantages to using hypergames revolve around four points:

1. It lays out a consistent, anticipative picture of many combinations of situations and options. This forces the planner to be more circumspective, but neither pessimistic nor optimistic. It invites new options to be generated that might lead to much better answers, such as the "parsimonious sensors" option heralded at the end of the Discussion section.
2. It forces one to consider that evidence in and around an unfolding emergency will be closer to the truth than the context during planning and anticipates real-time updating. Game theory always has generated but one answer for a given scenario, that of an *omniscient opponent* who can discern immediately any exploitable tendency that we have: situational beliefs and current beliefs are not even solicited. Practical advantages accrue when the team has rapid and effective communications to construct an evidential picture.
3. Hypergame theory challenges the assumption that any preplanning is complete and treats uncertainty as something to be continually assessed. It eschews complacency by asserting that the more uncertain that the planner is about the adversarial situation, the more credence that must be given to a devastating, worst case scenario (as per the discussion).
4. Yet, it represents that we can be lucky, too. Such luck can be "Divine Providence" (Washington 1777) or motivated security personnel who discover and pre-empt an attack. These people, like first responders, are heroes and we can even calculate their situational worth using hypergames.

At least in the near future, it seems that by considering scenarios such as the one included in this article, decision-makers may avoid the kind of surprise that plagues the naive, possibly saving lives and capturing the enemy.

One can certainly imagine an effective computer-based tool that might help the first response planners capture and recall this information and easily. I assert that such a tool should follow the guidelines for neo-symbiotic (Griffith 2005) systems in the 21st century. This requirement means that the human and the computer work together to multiply the effectiveness of both (Vane 2005).

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