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Computational Social Network Modeling of Terrorist Recruitment

Nina Berry, Teresa Ko, Tim Moy, Julienne Smrcka, Jessica Turnley, Ben Wu

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550

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Nina Berry**, Teresa Ko**, Tim Moy*, Julianne Smrcka*, Jessica Turley*, Ben Wu**

Sandia National Laboratories

**P.O. Box 969
Livermore, California 94550

*P.O. Box 5800
Albuquerque, New Mexico 87185-9012

Abstract

The Seldon terrorist model represents a multi-disciplinary approach to developing organization software for the study of terrorist recruitment and group formation. The need to incorporate aspects of social science added a significant contribution to the vision of the resulting Seldon toolkit. The unique addition of and abstract agent category provided a means for capturing social concepts like cliques, mosque, etc. in a manner that represents their social conceptualization and not simply as a physical or economical institution. This paper provides an overview of the Seldon terrorist model developed to study the formation of cliques, which are used as the major recruitment entity for terrorist organizations.

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1 Introduction

1.1 Seldon Recruitment Model Overview

The multi-disciplinary fields of computational modeling, social science, and agent-based systems collectively form the evolving field of complex agent-based modeling with special emphasis on social dynamics. Unlike the traditional economic and/or physical sciences approaches that used macro represents of institutions (e.g., governments, banks) and micro instantiations of internal organizations, the agent-based social models emphasize the societal aspects of the underlying application(s). This newly integrated field provides a finer granularity of simulation based on interactions and behaviors between the software agent representing individual humans. The Seldon toolkit was developed to explore and understand how these social dynamics directly influences the formation of tightly coupled groups with similar emotional states that leave them susceptible to potential recruitment from external entities. Observing these simulations provide a unique insight into how social relationships, societal rules, and environmental factors are integrated into a complete world model.

The Seldon toolkit represents a hybrid architecture that is different from the traditional computational social dynamic simulations because of its multi-level design containing individual agents, abstract agent(s), and interactions based on social networks. The individual agents represent the individual humans in the model and are based on the same basic structure with varied parameter values that evolve with the simulation and based on a randomized seed input. The architecture provides the ability to capture institutional concepts that are typically hidden in social norms and mores into software entities called abstract agents. The toolkit supports the interactions between the abstract agents and the individual agents based on multiple social networks that are either linked to the abstract concepts or associated with a desired social activity. These networks provide a means of gauging and restricting the interactions and relationship building of the agents to those entities inside of the actual individual network(s).

We developed a terrorist recruitment model based on the work presented in the book Understanding Terrorist Networks, by Marc Sageman [30]. The model provides one interpretation of Sageman's views on the Global Salafi Jihad movement influence over the unhappy state of the Muslim faithful around the world. After adapting his views to the Seldon social organizational model we were able to provide a terrorist recruitment model centered in a factious section of a European city. The model permitted the Muslim community to have several mosques with a range of conservativeness, which directly influenced the messages relayed to the attending participants. The abstract agents were used to capture the significant norms and mores of the European society, mosques, and the cliques (small groups of tightly bonded individuals). The individual agents represented the expatriate Muslim males located within this section of the European community. The concept of recruitment in the model was a combination of the emotional state of the individual agents, the strength of their relational bonds build with other agents, the participation in a clique, and the location of the clique. Based on these factors the recruitment would occur only if the clique was located in the conservative mosque and happened to be contacted by the terrorist recruiting agent (known as a bridge in Sageman's work). Since the recruiting agent only targeted groups the clique formation (see section 4.2.3 form more details) played a significant role in the overall simulation. A detailed discussion of the correlation between Sageman's work and the Seldon framework design is given in section 0. While this simulation cannot be used to predict the behavior of specific individuals, it provides a tool for understanding how social behavior in a variety of situations evolves.

1.2 LDRD Objectives

The objective of the Seldon – terrorist LDRD project was to use the existing Seldon software toolkit to develop a model for terrorist recruitment. To accomplish this overall goal the domain experts extended their knowledge by collaborating with domain experts on terrorist activities and creation. The team also collaborated and aligned their resulting model with the terrorist work of Marc Sageman [30] (see section 3.1 for details).

1.3 LDRD Deliverables

This LDRD deliverable was a prototype agent-based computational modeling toolkit for simulating the emergence of terrorists and terrorist-like organizations. The major tasks for this project included:

- Design and develop domain expert model for Middle-eastern terrorist groups.
- Extend the existing Seldon toolkit to accommodate the new terrorist model.
- Test agent-based social simulation using the terrorist model.

2 Modeling Terrorism with Computational Social Simulation

Several researchers have been exploring computational modeling and simulations to help analysts better understand terrorism. Table 1 summarizes the known research in agent-based computational terrorist models and each are described in detail in this section. The table is divided into two sections, agent-based and non-agent-based models. The agent-based models provide a significantly richer environment for studying complex systems by allowing the user to define behaviors at the individual level.

Table 1 Research on modeling and simulation of terrorism

Researcher	Research Topic	Threat Space
Agent-base Simulations		
Ian Lustick	Model of a Middle East Polity	Long-term (3-5 yrs); Understand spread of identities
Ed MacKerrow	Model of Middle East Socioeconomic Systems	Long-term (3-5 yrs); Understanding terrorists origin
Kathleen Carley	Dynamic Network Analysis – Destabilizing Terrorist Networks	Short-term (< 1 yr)
United States Marine Corp	Project Albert – Battlefield Wargaming	Real-time terrorist attack
Kathleen Carley	Biowar	Post attack analysis
Non Agent-base Simulations		
Weaver et al, 2001 [34]	Generating virtual opponents for the virtual training environment.	Real-time terrorist attack
SNL	WMD-DAC	Post attack analysis

Table 2 summarizes the key differences between four the agent-based models in Table 1, along with a comparison of the Seldon project. The rows in Table 2 cover six differences categories traditionally used to evaluate agent-based models, these include type of simulation, number of agents, time increments of the simulation, type of social network, internal group (clique) support, and adaptability of the agents. First, the models are investigating very different parts of the problem space. As a result, they differ markedly in their approaches and toolsets. The number of agents supported by each project ranges significantly from 12 to 260,000, depending on the granularity required in the results. The time steps are typically in the day-increments with simulations lasting months to years with the notable exception of real-time simulation of Project Albert.

Most of the researchers recognize the importance of social networks and have added them into their code. We must note, however, that each researcher has a different approach on representing the social networks and their dynamics. As for the formation and evolution of the cliques within the social networks, this is one area that has not been extensively developed for computational simulations. Both Ed MacKerrow and Seldon are making an attempt at this challenging dynamic.

Lastly, the individual agents in most of these models are non-adaptive, with the exception of MacKerrow's. Adaptive is herein defined as the modification of an agent's behavior rules as a response to its past interactions. In most of the models, therefore, the agent behavior rules at the final time step are the same as those at initiation. In short, there is no feedback control of the agents thereby resulting in reactive behavior.

Table 2 Agent-based modeling of terrorists

	Socioeconomic Model (MacKerrow)	DYNET (Carley)	Project Albert (USMC)	Biowar (Carley)	Seldon (SNL)
Simulation Type	MidEast Social Grievance	Disrupt. of Terror Orgs	Battlefield Tactics	U.S. Urban BioAttack	Terrorist Enlistment
# of Agents	1000s	12	30 to 50	260,000	200 to 1000
Time Steps	Day	Day	Seconds	4 hrs	Day
Social Networks	Dynamic & Multiple	Dynamic	No	Static	Dynamic & Multiple
Clique Formation	Yes	No	No	No	Yes
Adaptation	Game Theory	Yes	No	No	No

2.1 Middle East Polity (MEP)

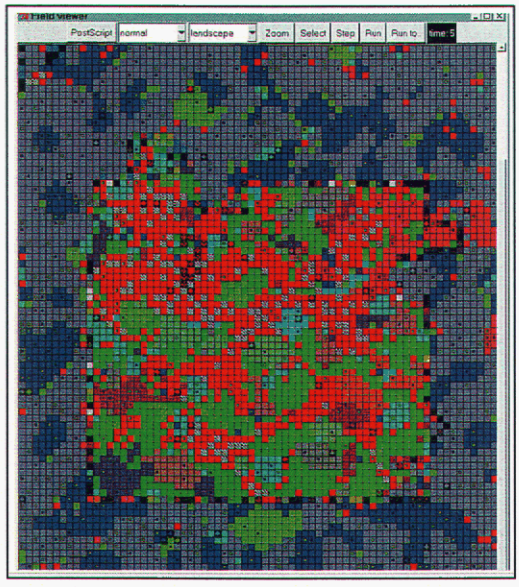

Figure 1: Middle East Polity landscape [23]

Ian Lustick [23], Professor of Political Science at the University of Pennsylvania, has developed an agent-based computer simulation platform (PS-I) for testing competing versions of constructivist theories. As example of this cellular automata-based approach, Middle East Polity (MEP) is an intriguing model of a typical Middle Eastern country and falls into the category of "toy models" in that it does not attempt to capture the ecological complexities of any specific country or group of countries. In fact, Lustick specifically asks researchers to use PS-I as a virtual laboratory to frame, test, and refine abstract theories, rather than experiment with real countries and situations.

Lustick draws an analogy to stripped down models of airplanes that are used in wind tunnels to test the effects of wing designs, but cannot otherwise fly themselves. MEP is therefore intended not to make "point predictions", but rather as a way of exploring behavior patterns that emerge from such systematic investigations.

The model runs on a 50 x 50 grid and is comprised of approximately 10,000 agents each with a repertoire (array) of identities, including "secular autocratic", "traditional patriarchal Islam", "Pan-Arab", and "Kurdish-like". Exploring the parameter space allows the user to manipulate variables such as globalization pressure thus revealing potential "future activities". By examining the distribution of outcomes, one can gain a sense of probable, improbable, or virtually impossible "futures" for MEP.

2.2 Threat Anticipation Program (TAP) Model of SocioEconomic Systems

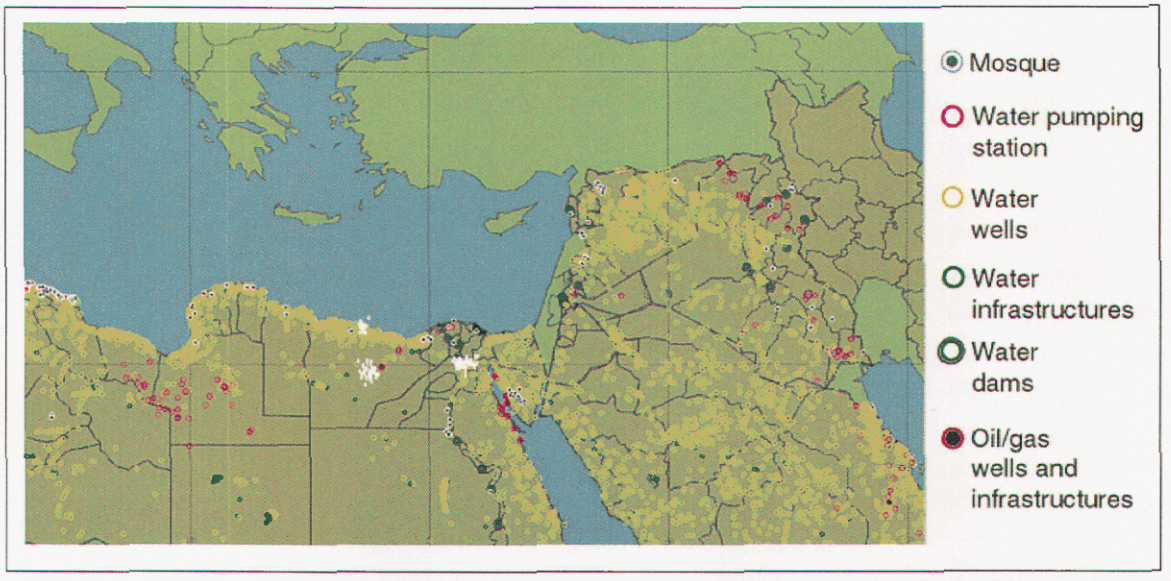

Figure 2: Snapshot taken from [24]. Agent distributed by regional demographics, for example the white clusters in the northern Egypt.

Researcher Ed MacKerrow of Los Alamos National Laboratories has been working on an agent-based model of a complex socioeconomic system in the Middle East [24]. His aim is to explore the "why" behind terrorist organizations in the Middle East by simulating the dynamics of the social networks and the spread of social grievances within those networks. His work is part of the Defense Threat Reduction Agency (DTRA) research known as the Threat Anticipation Program (TAP) that was established by Dr. Stephen Younger, former DTRA Director.

MacKerrow's TAP model places thousands of agents through the Middle East, each with numerous properties and behaviors, and allows them to interact for simulated years, thus producing a virtual history of the region. Unlike Lustick abstract MEP, MacKerrow endows his agents with personal attributes and allegiances that statistically match the actual demographics of the actual area. Moreover, the agents have a capacity to "learn" during the simulation and alter their behavior according to their history. For "learning", MacKerrow borrows from Peyton Young's social bargaining theory, based on the one-shot Nash demand game wherein agents compete, by bidding, to win an abstract "property", such as allegiance value. If the bidding is successful, the agents exchange values, bidirectionally and asymmetrically. By keeping track of bidding strategies over m times-steps, the agent's "learn".

Social grievance has been targeted as the summary metric for determining the propensity of agents to become terrorists. Other metrics include social repression and socioeconomics disadvantage. The spread of social grievance is modeled through repeated agent-agent interactions that result in the diffusion of social memes, also known as the "contagion" effect.

2.3 Dynamic Network Analysis

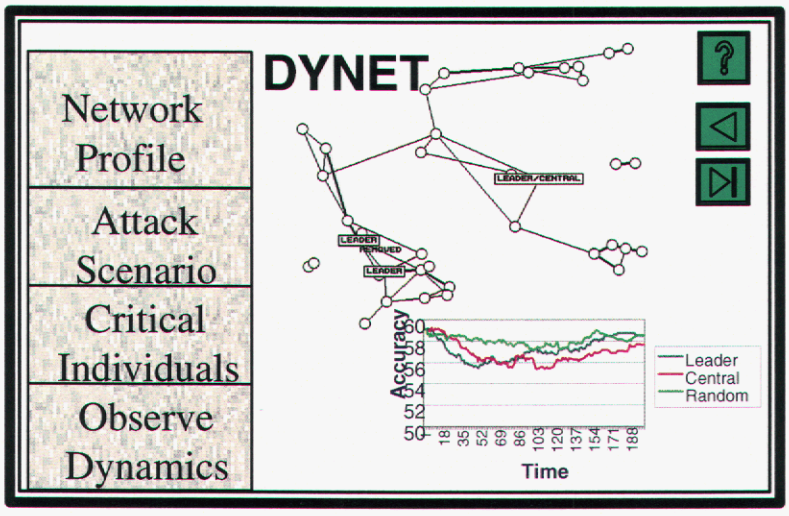

Figure 3: DYNET: A desktop tool for reasoning about dynamic networked and cellular organizations.

Kathleen Carley, Professor in the Institute for Software Research International at Carnegie Mellon University, has been developing an approach called dynamic network analysis (DYNET) that combines multi-agent modeling with traditional social network analysis [4]. In her research on terrorists, Carley explored the robustness of covert networks to different destabilization strategies using DYNET.

In her paper [4], Carley illustrated her approach by applying DYNET to a set of the Tunisia Embassy Bombing data set of 12 terrorists. She explored the effect of performance and subsequent adaptation of the network on the removal of Wadih al Hage (Agent 7) and Ahmed the German (Agent 5), see Figure 4. Agent 7 has the highest Degree Centrality and Between Centrality in the social network. In other words, Agent 7 is the best connected. Not shown in Figure 4, Agent 5 has the highest Cognitive Load and Task Exclusivity. Agent 5 therefore has important and semi-exclusive domain expertise. However, since the removal of neither agent actually crippled the group, the actual effects were small, albeit statistically significant. Carley showed that removing Agent 5 both lowered performance more and retarded future performance growth. Therefore, removal of Agent 5 was deemed to be more destabilizing.

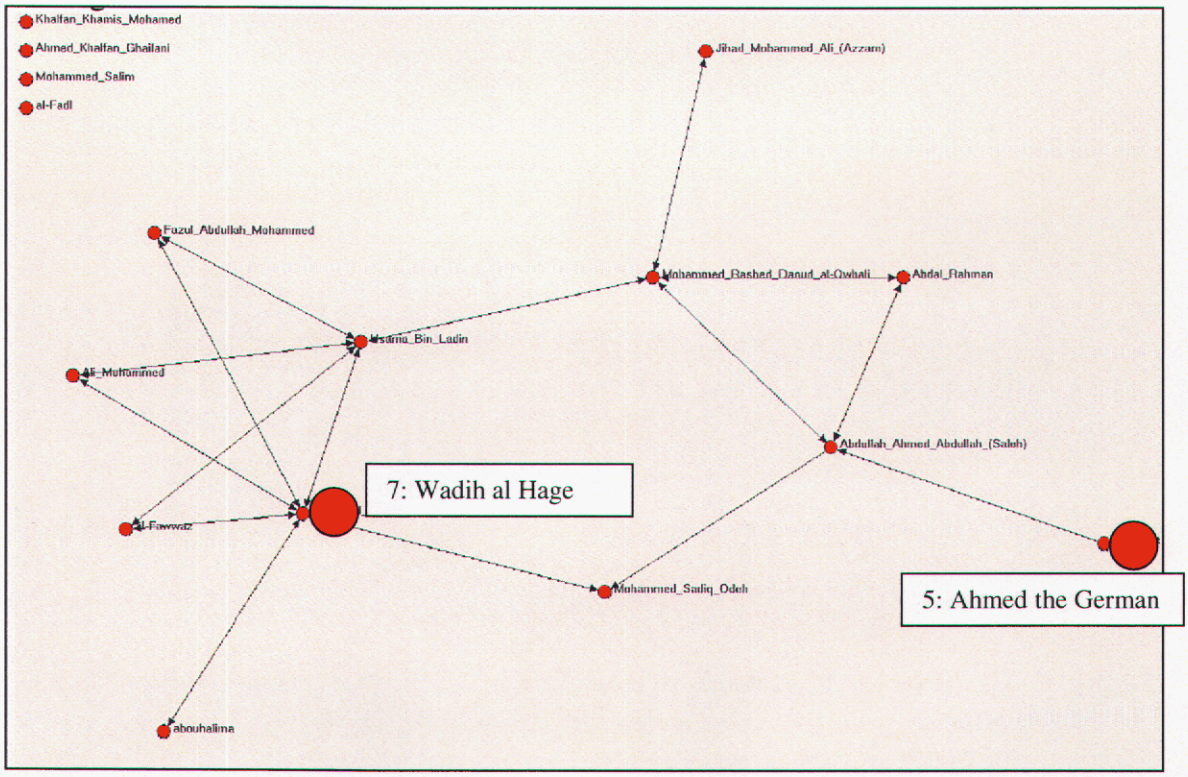

Figure 4: Snapshot [4] of the social network from the Tunisia Embassy Bombing data.

2.4 Project Albert

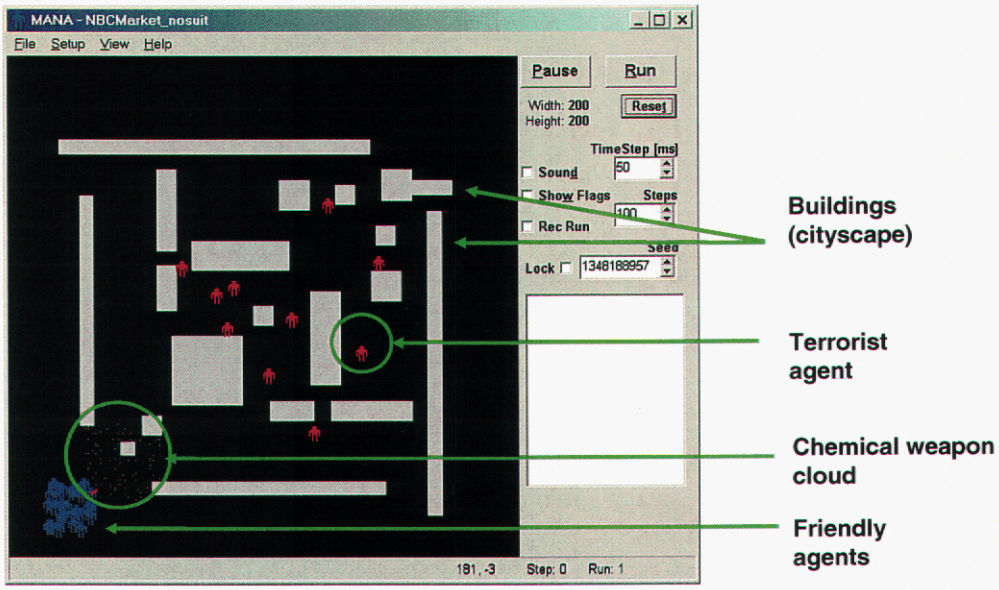

Figure 5: Simulation from Project Albert

The U.S. Marine Corp has been applying complexity theory to studying the human dimension of land warfare. For the most part, the Project Albert models, or distillations, are intentionally simple while providing powerful insights into emergent macroscopic behavior that result from the collective interactions of individual agents.

Types of questions that might be posed to the Project Albert modelers:

- When and how should Command and Control be centralized or decentralized?
- What is the appropriate force mix required for operations in a littoral environment?
- What are the relative merits of firepower, mobility, situational awareness, stealth, and information operations in a reconnaissance/counter reconnaissance situation?
- What is the impact of reconnaissance on mission success?

The application of Project Albert to terrorists tends to be very tactical as illustrated in Figure 5 that shows a scenario involving a terrorist attack with chemical warfare agents. However, Wendell Jones and Nancy Hayden [13] of the Advanced Concepts Group have extended the tool to exploring the same enlistment processes that are investigated in this paper. One of the primary differences in their approach is the absence of social networks that is central to the Seldon Model. Figure 6 shows a diagram summarizing their terrorist model. In brief, they observed the emergence of agent clusters in the absence of any top-down recruitment or leadership.

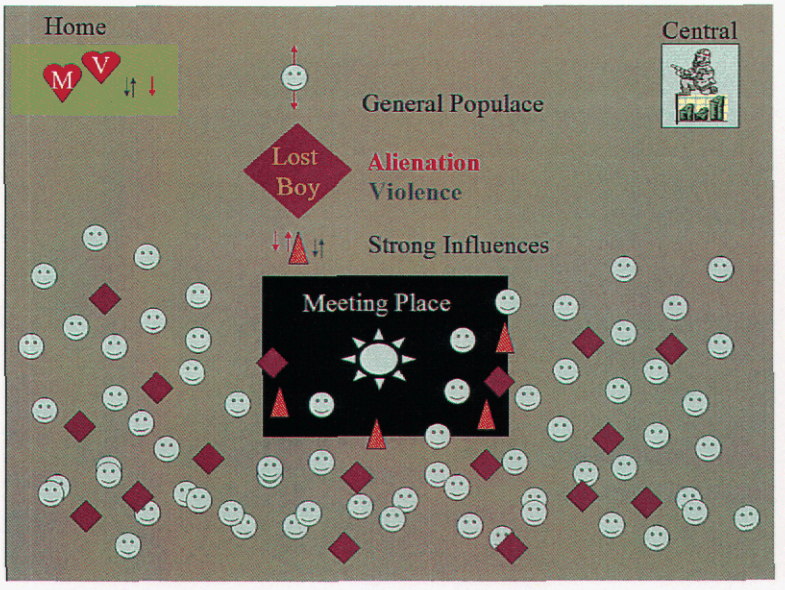

Figure 6: Project Albert applied to terrorists clustering

2.5 Biowar

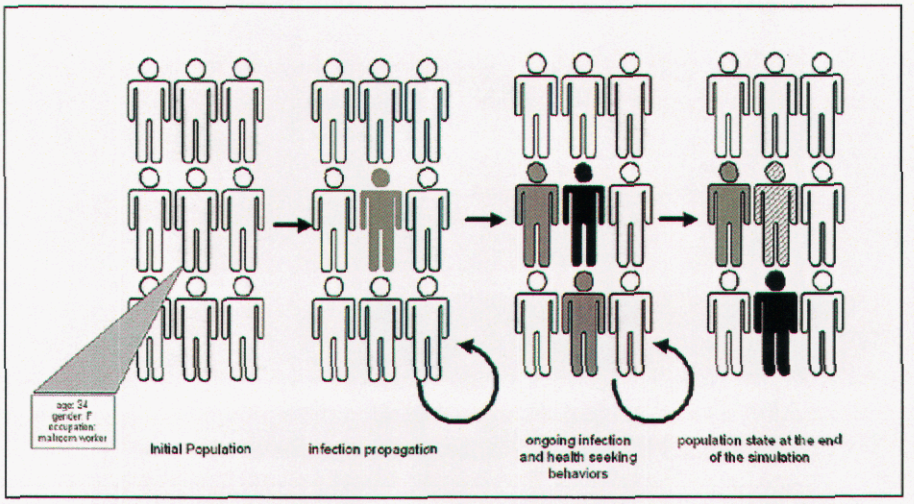

Figure 7: Biowar diagram taken from [5]

Kathleen Carley has been developing Biowar, a computational agent-based model of a terrorist attack on a city with a biological agent. In this model, she has combined social networks, communication media, disease models, demographically accurate agents, wind dispersion models, and a diagnostic errors model into an integrated package. Biowar enables analysts to ask and answer "what if" questions exploring the repercussions from various attacks and using different containment policies. Biowar could also provide potential cues of biological attack from indicators such as absenteeism, medical web hits, medical phone calls, insurance claims, death rate, and over-the-counter pharmacy purchases. Carley reported that they have already simulated runs from several geographical areas including San Diego, Pittsburgh, Norfolk,

and Hampton. The number of agents in the simulations ranged from 52,000 to 260,000. Scenarios simulated include no attack, anthrax attack, smallpox attack, inside and outside building.

2.6 Generating Virtual Opponents

Weaver Ransom and his colleagues at University of Pennsylvania are using a hierarchical game theoretic approach to develop a terrorist generator that can be used for existing virtual reality training environment, such as the military's Joint Semi-Automated Forces (JSAF) software [5]. The long-term goal is to allow the user to select the opponent of choice – e.g., Iraqi Republican Guard, Hamas-type Suicide Bomber, or clandestine minions of Osama bin Laden. The researchers analyze actual organizations and capture their individual differences through a "Performance Moderator Function" scorecard. Assuming rational agents and developing a game theory matrix of agent utilities, the researchers can then calculate a probabilistic Course of Actions table. They have tested their approach on a scenario involving a bank bomber approaching a vehicle check point, but reported no results.

2.7 Weapons of Mass Destruction-Decision Analysis Center (WMD-DAC)

Figure 8: Systems analyst Dawn Manley (standing) describes the WMD-DAC computer program to a group of observers.

WMD-DAC is a simulation architecture tool built by Sandia that provides policymakers and tactical personnel the unique opportunity to play through an interactive, real time, "what if" computerized urban terrorist attack from WMDs, like biological agents. While not strictly an agent-based simulation, WMD-DAC does model the repercussions from a WMD attack on an urban area, like San Francisco, like the spread of a disease. The users are provided accurate visualizations on relevant simulation output, such as health data from area hospitals and the origin of the patients. The interface allows the end-user the opportunity to participate and interact with the real-time simulation. For instance, the County Health Official might chose to inoculate the entire population on day 3 before the first case of Anthrax is actually confirmed.

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3 Seldon Terrorist Model

3.1 Sageman Theory on Global Salafi Jihad (GSJ) Enlistment

The design of the terrorist model is based upon the work of Marc Sageman [30]. Marc Sageman, Ph.D., M.D., is a former Foreign Service officer who was based in Islamabad from 1987 to 1989, where he worked closely with Afghanistan's mujahedin. He has advised various branches of the U.S. government in the war on terror. Sageman is a forensic psychiatrist in private practice in Philadelphia. We drew upon Sageman's pre-publication manuscript and other writings. We also consulted directly with him during the model development as to the model's fidelity to his initial data.

Sageman's work focuses specifically upon what he calls the Global Salafi Jihad (GSJ). This is a violent jihadic movement proclaimed by Osama bin Laden in a 1996 *fatwa*. Its ultimate goal is to establish a Muslim state, reinstate the fallen Caliphate and regain the lost glory of the Caliphate. As the United States would resist this, the Global Salafi Jihad strategy calls for defeat of the US (the 'far enemy') before 'corrupt' elements of modern Islamic states (the 'near enemy') are attacked.

Sageman has acquired data on 172 Global Salafi mujahedin. The data was acquired from unclassified sources such as published interviews, court testimony, news reports, and related items. His thesis, derived from analysis of this data, is twofold. First, the mujahedin do not exhibit significant psychological or social pathologies: they are 'normal' people. Second, they have formed into social networks or 'clusters' based on some common experience. It is these informal clusters rather than any formal organization that are the basis of the Global Salafi Jihad movement.[1]

This analysis of the basis for participation supports the integrated agent-based and social network modeling approach we have taken with Seldon. Since the mujahedin or actors (individual agents in the terminology of our model) do not exhibit any significant pathologies, they can be defined as classes of actors rather than as specific individuals. Therefore, the absence of a cognitive module at this stage of model development does not significantly detract from the fidelity of the model.

The common experiences that define either the attractiveness of participation in the Global Salafi Jihad, or participation in the Jihad itself allow for the inclusion of what we have called 'abstract agents' such as mosques or 'cities' (general social environment). This moves us away from the highly reductionist nature of some agent-based models by giving existential standing to collectivities as well as individuals (see [9]). The importance of social connections to the growth and development of the terrorist cells further illustrates the power of social network within the overall modeling process.

Sageman's analysis draws from both the psychological and social (or 'environmental') analytic approaches to terrorism. The psychological approach focuses on the individual. This research has looked for a particular personality constellation or composite of psychological factors that characterize the terrorist, such as self-esteem, family constellation, level of aggression, level of depression, and level of impulse control. As noted earlier, Sageman's analysis concludes that there is no significant level of pathology among the subjects he interviewed. This is supported by other literature in the field (see, e.g. [27])

The psychological approach also addresses motivations for joining terrorist groups. Interviews with terrorists have yielded statements by the interviewees that their participation in the terrorist group

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[1] Because the Global Salafi Jihad is described as a 'movement' rather than as an organization with corporate existence and some formal structure, we will speak of engagement with the movement as 'participation' rather than 'membership.'

represented the first time in their lives that they have experienced a sense of belonging [27]. Literature on fundamentalist religious movements such as the Global Salafi Jihad supports this finding. The literature suggests that these types of fundamentalist movements gain adherents in situations of rapid social change in which moral structures become unclear or ambiguous, and the sense of community and the behavioral codes communities provide tends to disintegrate (see [28]).

This moves us to the second theoretical frame or analytic approach, the sociological, or environmental. This approach considers terrorists as social phenomena, and focuses not on individual participants but on groups. It investigates the environment from which participants are recruited, looking for differences between that social milieu and those which do not spawn terrorism. The most common iteration of this approach is that which posits the 'failed state' in the Middle East as the precipitating factor for the growth of the jihadic groups. Under this scenario, religious groups fill the vacuum created by the absence of social support services and structures normally provided by the state. The provision of services and structures opens the door for acceptance of the group's ideology. An alternative scenario integrates well with the psychological approach described above, and thus supports Sageman's analysis. If a community marginalizes a group of individuals or causes them to feel powerless, they will seek structures within which they can regain a sense of self-esteem and power. If mainstream society offers no road to success, it will be sought (or created) through alternative communities such as extra-legal groups like terrorists. Under this scenario, the groups will not need to 'recruit' in a formal or active sense. New members will seek out the group to satisfy certain socio-psychological needs. In fact, we see this happening in Sageman's work.

Sageman has identified four large clusters of mujahedin: the 'Central Staff,' the Core Arab Cluster, the Maghreb Arab cluster, and the Indonesian cluster. The Indonesian cluster differed significantly from the other three in the way it gained new participants; we did not include its architecture or attributes of its participants in our model. The other three were more similar, although the Core Arab and the Maghreb Arab clusters were more similar to each other than were they both were to the Central Staff cluster. The Core Arab cluster was the largest. Data on and the social architecture of this cluster forms the basis of our model. It is worth quoting Sageman's description of both the Core Arab and the Maghreb Arab clusters at some length, as it will highlight some of the key elements of our modeling architecture.

> The Maghreb Arabs, either first- or second-generation in France, grew up feeling excluded from French society and were generally not religious as young people. They were still upwardly mobile compared to their parents, but in the process of moving up, became isolated and sought friendships in local mosques. The Core Arabs, who grew up in core Arab lands, came from a communal society and belong to the most communal of all religions. They were isolated when they moved away from their family and friends and felt particularly lonely and emotionally alienated in this new individualistic environment. They especially felt the lack of spirtualism in a utilitarian culture. They were underemployed and felt discriminated against by the local society. They felt a personal sense of grievance and humiliation… [30]

Note that both groups were living in a social environment from which they felt alienated. They sought social connectivity through the development of small groups of close friends, and through the mosque, which was initially viewed as a connection to the 'familiar,' and only later became a focus for religious sentiment and associated political action.[2]

Sageman notes that each mosque provides a particular type of religious and/or communal message. A small minority preaches the Global Salafi Jihadic message of religious-political violence; the others fall

[2] The conflation of church and state in Islamic theology leads to the conflation of religious and political action.

towards the more pacifists' end of the spectrum. Which mosque an individual attends is a function of his level of alienation and consequent attractiveness of the type of message the mosque offers, and of the interests and attendance patterns of his close friends.

The process observed by Sageman for growth of the Global Salafi Jihadic movement is as follows. Strongly alienated expatriates either form close relationships with others like them (form a clique) and then find a mosque preaching a sympathetic (i.e. Salafi Jihadic) message, or are attracted to such a mosque and so find other, sympathetic individuals. These small groups, or cliques, then contact or are contacted by a 'bridge.' The 'bridges' are individuals who (almost always) have had some experience in Afghanistan and so have connected in some way to the 'Core Staff' or the central al Quaida cluster. The 'bridge' vets the clique in some fashion and may or may not help it acquire the resources to engage in its own 'Afghani experience,' that is, to travel to the Middle East for training and further indoctrination. Only after such training will the individuals be considered 'full participants' in the Jihad. Note that individuals move through the process as a group, or clique.

The process around which Seldon is built is as follows. The actors in Seldon are expatriate Islamic young adult males (represented by an 'individual agent'), living in societies (which are represented as 'abstract agents') which have some level of tolerance of them, ranging from intolerant to fully accepting. Interaction (represented as contact) with the society causes the agents to become more or less dissatisfied (or disgruntled), depending upon the tolerance level of the society with which they interact. The world within which these young men live also includes mosques (another set of 'abstract agents'), each of which preaches a message imbued with more or less of the Global Salafi Jihadic ideology. The young men form acquaintance networks. These acquaintance networks solidify into small groups of close friends (cliques) defined by common levels of disgruntlement. The cliques may or may not make contact with a 'bridge' while attending a mosque preaching a Jihadic message. The Seldon model does not take the process any further.

3.2 Seldon's Implementation of Sagemans' Pipeline

Sageman's primary enlistment pathway into the Global Salafi Jihad is linearly represented in Figure 9. This diagram begins with the expatriate or isolated individual attending a radical mosque, where they are attracted to others with similar isolationist feelings. These individuals become a group or clique that is observed by the jihad agent and later enlist the clique into the global Salafi Jihad movement. Seldon's implementation of this pipeline required significantly more details than were presented in his manuscript. We found that we needed to interact with Sageman to gain sufficient understanding to codify the microprocesses that are summarized in Figure 10 that outlines the implementation of the overall enlistment pathway.

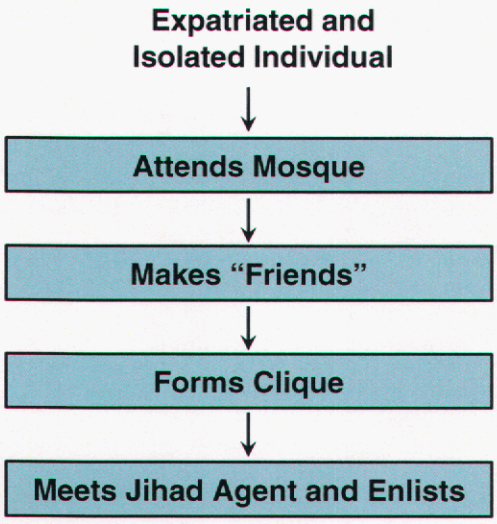

Figure 9: Pathway to the Global Salafi Jihad via Sageman's pipeline

Before describing the implementation, we must first describe the multi-scale agents that were developed for this model. While most agent-based models are composed of individuals as their basic units, Seldon also supports agents representing different granularity of social scale (i.e., individual to city):

- Individual Agents
- Cliques Agents
- Mosques Agents
- City Agents

Each increasingly larger-scale agent is composed of smaller-scale agents, and is more than simply the aggregate of those agents, a super-organism in other words. For instance, a Mosque Agent contains both Cliques and Individual Agents. The Mosque Agent has attributes that are influenced with the sub-agents, but also independent of the sub-agents.

The Seldon implementation in Figure 10 is basically a day in the life (one computational time step) of an individual agent ("Expatriate"). The sequence of steps was arbitrary. With a model containing up to 500 individual agents and typical runs ending at $t = 600$, we are simulating more than a million agent-agent interactions during the course of one run. Aggregating the results from all these interactions ultimately represents the Sageman representation of Figure 9.

Every "day", an individual agent first decides whether or not to attend a mosque. That decision is driven by its degree of social isolation, or a lack of strong social network, as per Sageman. The individual agent then interacts with the super-scale City Agent. This interaction represents the summation of all the actual interactions with parts of a city not represented elsewhere in the model and that will potentially influence the individual agent's Disgruntlement. For example, members of the native population, immigration laws, and media are possible elements of City that can change the Disgruntlement of the individual agent.

If the individual agent has chosen to attend a mosque, then that individual agent interacts with the "Mosque" Agent. As with the interaction with super-scale City Agent, the Mosque Agent interaction is meant to capture all the elements of the Mosque experience influencing the individual agent's Disgruntlement that are not explicitly represented elsewhere. For example, the sermon from a charismatic

religious leader may significantly increase the Disgruntlement of an individual agent and that would be captured here.

In the next step, the individual agent interacts with the other members of its clique only if it belongs to that clique. The individual agent then interacts with other individual agents. During this interaction, a relationship between the two individual agents can form and strengthen (or weaken), thus changing each agent's social network. The second outcome of the interaction is that the individual agents can transmit their Disgruntlement to each other and respond according to rules described in the next section.

Lastly, the individual agent, as part of a clique, may meet a Jihadi Bridge, an agent that provides a conduit to the movement. This meeting is a stochastic process. If there is a chance meeting, then the Bridge agent will evaluate the clique for worthiness ("Pass?" on the diagram) to proceed to the Training Camps in Afghanistan. If they are worthy, then they are essentially removed from the simulation. If not, then the day is completed for that individual agent.

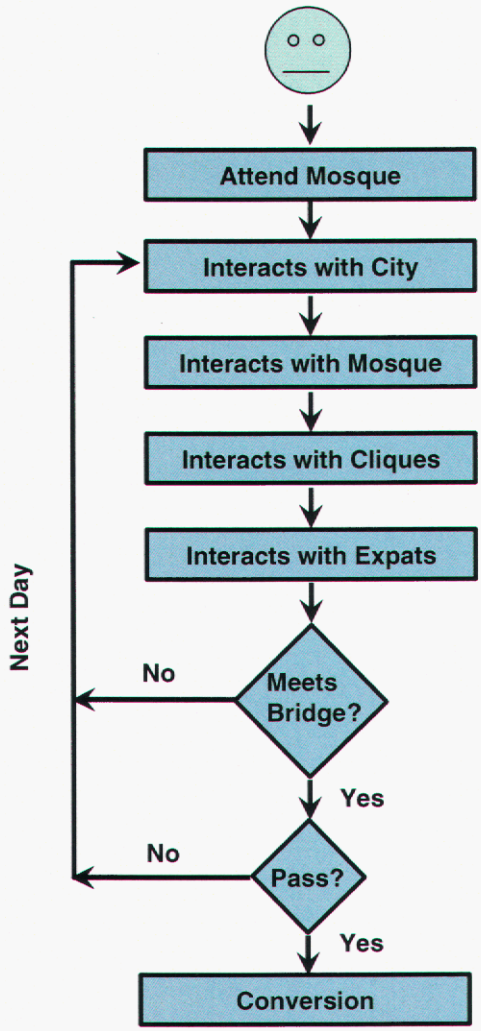

Figure 10: Seldon implementation of Sageman Pipeline

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4 Seldon Model Development

4.1 Agent Description

The model contains two categories of agents: individual agents, a traditional computation agent used to represent people, and abstract agents, a conceptual agent used to incorporate social concepts into the model. In the Seldon model, we have two types of individual agents: an *expatriate*, a foreign national who is isolated from the community and terrorist organizations, and a *bridge*, a foreign national who has the ability to connect an expatriate with a terrorist organization. The three types of abstract agents are the *society*, the *mosque*, and the *clique*. The *society* captures the culture of the physical location in which these agents reside encompassing societal concepts such as the willingness to accept foreigners in their world. The *mosque* represents the religious and social gathering place for expatriates. The *clique* captures the dynamics of groups of individuals who are all close friends with one another.

4.1.1 Abstract agents

The three abstract agents are designed in relation to individual agents. Abstract agents are characterized by:

- attributes, characteristics used by other agents to determine interactions,
- members, agents this abstraction can influence or be influenced by,
- membership criteria, to determine on a day to day basis membership,
- type of influences, affect of an agent's influence over one another,
- optional, an associated network containing the members of this abstract agent.

Each of our abstract agents is able to represent their respective concepts through these characteristics. The *society* has one attribute: its attitude towards expatriates. This attitude is captured through a normal distribution with an end user specified mean and standard deviation, reflecting the different possibility of a society's culture and the varying perspective individuals has of their society. At each time step, the *society* uses an individual's attributes to determine if it can influence that individual. *Society* has a unidirectional influence from the *society* to the individual. This influence can be described according to the following equation:

$$D_A(t) = D_A(t-1) + \delta(x) \cdot \mathrm{N}(\mu, \sigma^2),$$

$$\delta(x) = \begin{cases} 1 & \textit{if individual A interacts with society} \\ 0 & \textit{if individual A does not interacts with society} \end{cases},$$

where D_A is the disgruntlement of an individual agent A, t is the time step, and $\mathrm{N}(\mu, \sigma^2)$ is a Gaussian distribution with a mean of μ and a standard deviation of σ^2. For $t >> 0$, the closed form version of this equation can be approximated by:

$$D_A(t) = P_A(x) \cdot \mu,$$

where $P_A(x)$ is the probability of an individual to interact with *society*.

The Seldon model allows for the representation of multiple mosques. Each *mosque* has one attribute: its disgruntlement. This value is set by the end user prior to the simulation run and is held constant throughout the run. The disgruntlement of the *mosque* is used for both determining the membership of the

mosque and influencing the members. There are two factors that affect membership to a *mosque*: an individual's sense of isolation and an individual's stickiness towards the mosque which derives from the natural tendency for a person to stay where they are. An individual's decision to attend a mosque on a day-to-day basis is shown in Figure 11. If an agent attended a mosque the day before, that agent must first decide whether or not continue to attend the same mosque. An agent's decision is based on its stickiness towards the mosque, which incrementally increases as the agent continues to attend the same mosque, shown in Figure 12. If an agent decides against attending the same mosque or did not attend a mosque the previous day, an agent decides between attending any random mosque and not attending a mosque at all. An agent uses isolation to determine its attendance, shown in Figure 13. The more isolated an agent is, the more likely the agent will choose to attend any of the random mosques.

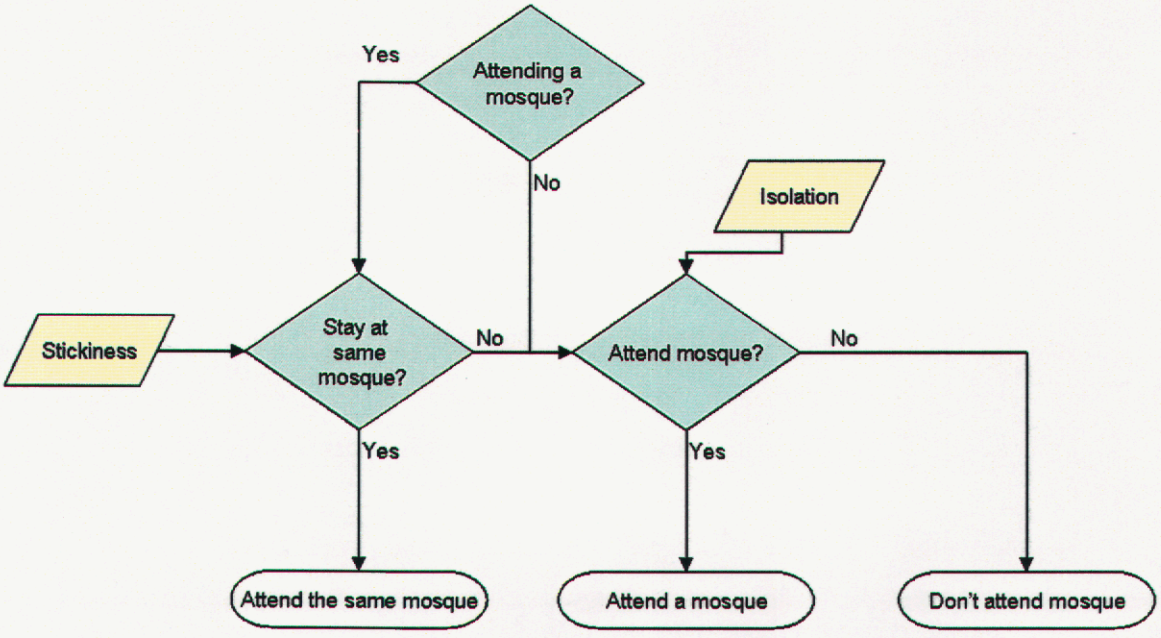

Figure 11: Flowchart of an individual's decision to attend a mosque.

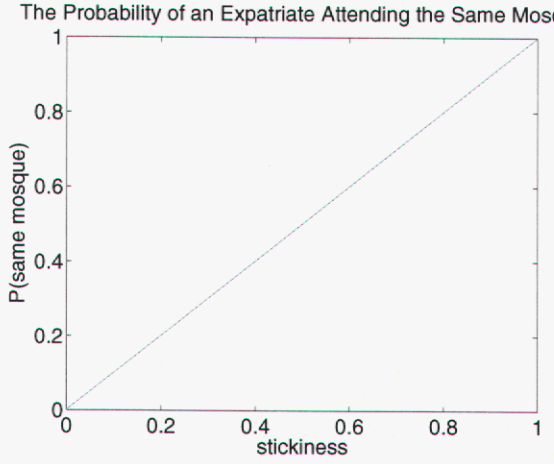

Figure 12: Probability of expatriate attending the same mosque. The more "stuck" an agent is to a mosque, the more likely they will continue to attend the same mosque.

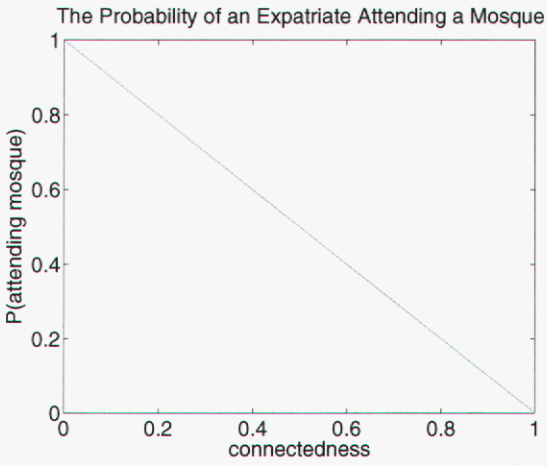

Figure 13: Probability of expatriate attending a new mosque. The more connected (less isolated) an expatriate is, the less likely it will attend a mosque.

Each time step, the *mosque* pulls its members closer to its disgruntlement, gradually infusing its message to its members. In addition, the *mosque* incrementally increases each member's stickiness towards itself. Stickiness is a measure of the combination of many different comparators between the mosque and the agent. The first factor in computing stickiness comes from the fact that negative message are more compelling then positive messages. Therefore, a more disgruntled mosque will be stickier than a neutral mosque. Another factor is how closer an agent's disgruntlement is to the mosque's. If an agent's viewpoint coincides with the particular mosque, they are more likely to become stuck to that mosque. The two remaining factors compare an agent with the other member's of the mosque. If it finds that the other agents attending the mosque are similar to it, it will be more likely to stick to that mosque.

This process is described in the following equation:

$$S_M(a,t) = S_M(a,t-1) + w_{MD}\left(\frac{1}{2}(1-D_M)\right) + w_{MDS}\left(1-\frac{1}{2}\left|D_a - D_M\right|\right) +$$

$$w_{ADS}\left(1-\frac{1}{2}\left|D_a - \bar{D_a}\right|\right) + w_{ABS}\left(1-\left|\bar{i_a} - \sum_{i\in B} i_a\right|\right),$$

$$w_{MD} + w_{MDS} + w_{ADS} + w_{ABS} = 1$$

where $S_M(a,t)$ is the measure of how stuck an agent a is to a mosque M at time t, D_X is the disgruntlement of agent X, $\bar{D_a}$ is the average disgruntlement of members of the mosque, i_X is the binary value of the $i'th$ discrete attribute, $\bar{i_a}$ is the average value of the binary attribute, w_{MD} is the weight of the mosque's disgruntlement, w_{MDS} is the weight of the similarity between the mosque's disgruntlement and the agent's, w_{ADS} is the weight of the similarity between the average disgruntlement of the mosque members and the agent's, and w_{ABS} is the weight of the similarity between the discrete attributes of the mosque members and the agent.

The *clique* has two attributes: its disgruntlement and threshold for enlisting in a terrorist camp. The disgruntlement of a *clique* is the average disgruntlement of all its members. Each day, the *clique* pulls its members closer to its disgruntlement, gradually making each member more similar to one another. *Clique*s are created each day through the *strong bonds* network by examining the connectivity of the agents within the network. The mechanism for forming *cliques* will be described in greater detail in Section 4.2.1.2 and Section 4.2.3.

4.1.2 Individual agents

Individual agents are represented people in the model and are defined by the following three characteristics:

- attributes, characteristics used by themselves and other agents to determine interactions
- social networks,
- and, relationships.

The *expatriate* has a multitude of attributes, some which have been described in relation to the abstract agents in Section 4.1.1: isolation, disgruntlement, stickiness to mosque, outgoing/shy, and additional undefined binary attributes. The values of an *expatriate*'s attributes define how various agents will influence it and change as a result of the influence. Individuals exist within the context of multiple social networks. Each has its own unique place within their self-defined set of social networks, providing a unique perspective for individuals. These social networks limit the formation of relationship bonds, allowing only connected agents to interact.

The *bridge* is the simplest of all the implemented agents. Its attributes, isolation and disgruntlement, are fixed at complete isolation and disgruntlement. Because by nature, a *bridge* is an isolated disgruntled individual, its interactions never result in the formation of bonds or affects its disgruntlement index. An interaction with a *bridge* is an *expatriate*'s only channel to the terrorist camps. Research has shown an individual will not decide on its own to enlist in a terrorist camp. In addition to being a disgruntled individual, an *expatriate* must also belong to a disgruntled *clique*. If such an individual interactions with a *bridge*, the *bridge* must then decide whether or not the *individual* has the needed characteristics to be entrusted with a direct connection to the terrorist camp. To model this decision, we have used a simple probability to determine whether or not an *expatriate* is converted.

4.1.2.0 Disgruntlement

'Disgruntlement' reflects the agent's general level of (dis)satisfaction. It is a function of the agent's relationship with society. For purposes of this model, disgruntlement reflects the elements of alienation and anger the expatriates feel. Disgruntlement can range from –1 (very disgruntled) to 1 (very 'gruntled' or not disgruntled at all). Expatriates disgruntlement is initialized using a Gaussian distribution. As the model runs, an agent's level of disgruntlement will change as the agent comes into contact with society. If the society (abstract agent) is very intolerant, each contact with it will increase the agent's disgruntlement level. If society is accepting, the agent's level of disgruntlement will go down upon contact.

4.1.2.1 Discrete attributes

An *expatriate* has three discrete attributes which represent the multitude of characteristics an individual has, such as personality traits, ethnicity, activity preferences, etc. We have limited the number of discrete attributes to three resulting in eight subpopulations, a small enough set for evaluation purposes. Ultimately, the model is capable of handling an unlimited number of discrete attributes, each to represent a specific characteristic. These attributes enable friendships to form based on the similarity between two

agents. One of the three attributes has been designated as the outgoing/shy attribute which is used by the *society* abstract agent to determine membership each day. The probability of interacting with society can be varied according to whether or not an agent is outgoing or shy. For example, if an agent is outgoing, it can have a higher probability of interacting with society than a shy agent. Depending on the society, this can result in a greater negative or positive affect on the outgoing agent.

A *bridge* has no explicitly defined discrete attributes, because these attributes are only used to determine the strength of relationships or membership to a mosque. It never forms relationships and is fixed to a jihadi mosque.

4.2 Model Dynamics

4.2.1 Agent Interactions

The model contains different levels of agent interactions, which build relationships and alter the emotional behavior of the agents involved in these occasional meetings. The interactions in Seldon occur between sets of individual agents and between individual agents and abstract agents. These behaviors are defined by the two categories of model dynamics known as convergence and relationships. When two agents meet their degree of attractiveness to each other is represented by a set of converging emotional attributes that cover issues reflecting the happiness or acceptance an agent feels at a given timeframe. To refine the interactions of the agents by dictating how their relationships form and evolve based on the convergent behavior of the agents. Collectively these two model dynamics produce a varied level of different interactions and behaviors.

4.2.1.0 Convergence

When two agents (either two individuals or an individual and an abstract agent) come together, they have some level of attractiveness for each other (represented as 'stickiness' in the case of the mosque abstract agent). Their interaction causes them to exchange affect and attitudes (or 'gruntlement') according to an exchangeable rule set (either Linear Reinforcement and Linear Attraction rules), which is described later. This exchange will cause each of the agents to move up or down the disgruntlement scale symbolizing a two dimensional process. One dimension represents the underlying cause or reason for agents to come together (the 'attractiveness' factor) for the purpose of interactions. The second dimension deals with understanding why there are changes in their disgruntlement level when they form these relationship(s).

The SELDON model draws upon the psychological literature to construct this part of the model. The literature strongly supports the notion of homophily as the basis for the attraction of two agents, that is, like will seek like ([3]; [7];[11], [18], [21], [22], [31]). Contrasting attitudes produce the opposite effect, that is, individuals with contrasting moods will repel each other rather than exhibit a neutral force ([21], [22]).

There is a great deal of literature on how emotional levels change when individuals form a relationship. This "social transmission of emotion" [1] occurs largely on an unconscious level as stated in [14], [8], [15]. However, given that individuals will seek out like individuals, and will become even more like close acquaintances, friends, or spouses (i.e. that emotional transmission does take place), there is very little literature on how this emotional convergence happens [1]. Strack and Coyne [32] found that happy people working with depressed or sad people tended to become depressed very quickly. Gotlieb and Robinson [12] had similar results. Therefore, at best, we find evidence (as cited above) of movement of the more positive agent toward the more negative member of the dyad.

To allow users to experiment with different ways of exchanging affects or attributes, the model defines a exchangeable rule set. For this particular terrorist model, we have defined two rules: Linear

Reinforcement and Linear Attraction. Linear Reinforcement incrementally increases or decreases both agents' disgruntlement by a constant value according to this equation:

$$D_A(t) = D_A(t-1) + c,$$
$$D_B(t) = D_B(t-1) + c,$$

where D_A is the disgruntlement of an individual agent A, D_B is the disgruntlement of an individual agent B, t is the time step, and c is a constant specified by the end user. Varying c varies the strength of the reinforcement: the positive value results in happier agents while the negative value results in disgruntled agents. The effect of the interaction is directly impacted by the size of the absolute value of this equation. Linear Attraction incrementally draws both agents' disgruntlement closer or further away from their average disgruntlement, using this equation:

$$D_A(t) = D_A(t-1) + c,$$
$$D_B(t) = D_B(t-1) - c,$$

where $D_A < D_B$. If c is positive, the disgruntlement of both agents move towards their average. To damp oscillation, the changed disgruntlement is not allowed to exceed the average.

Interactions between individual agents are separated into three types: interactions between two disgruntled agents, interactions between two happy agents, and interactions between a disgruntled agent and a happy agent. Each type of interaction is governed by its own set of rules, allowing the end user to specify the constants associated for each type.

Convergence is also used between individual and abstract agents. The *society* uses the linear reinforcement rule to incrementally influence an individual agent. The *mosque* and *clique* uses the linear attraction rule to make individual agents more similar to the respective abstraction.

4.2.1.1 Relationships

We have limited the number of acquaintances or relationships an individual can form by putting a cap on the amount of 'relationship energy' an individual has to expend. This tracks nicely with research on social network size. Brewer and Webster [2] found that as individuals are added to acquaintance networks, others are forgotten. Jin [17] used computer simulations to demonstrate that there is an upper limit on the number of friendships an individual can have, i.e. the size of the social network. Hill and Dunbar [16] suggested that maximum human group size was limited by neocortical development to about 150 individuals, with a concurrent assumption that the size of the group with which an individual has strong bonds is smaller than that—but also has an upward bound.

Individual agents have the opportunity to form relationships with one another through their interactions during the day. A similarity percentage is computed for two agents by comparing their discrete attributes and disgruntlement, using this equation:

$$S(a,b) = w_d\left(1 - \frac{1}{2}\left|D_A - D_B\right|\right) + w_b \sum_{i \in B} \left(i_A \otimes i_B\right),$$
$$w_d + w_b = 1,$$

where $S(a,b)$ is the similarity percentage between two agents, D_X is the disgruntlement of agent X, i_X is the binary value of the $i'th$ discrete attribute, w_d is the weight of the similarity between

disgruntlements, and w_b is the weight of the similarity between discrete attributes. Because it is unknown which factor, an individual's fixed attributes or its malleable ones, weigh more heavily in forming relationships, we have allowed for the flexibility in the model to test different weightings. The similarity between agents is used directly in the formation of the relationships between agents, as shown in Figure 14. The actual change shown in this graph is a gaussian distribution around the line to capture the additional attributes not explicitly defined. Similarity between two agents is directly proportional to the mean change of the strength of the relationship between two agents. The actual change in the strength of a relationship is a Gaussian distribution around the mean value.

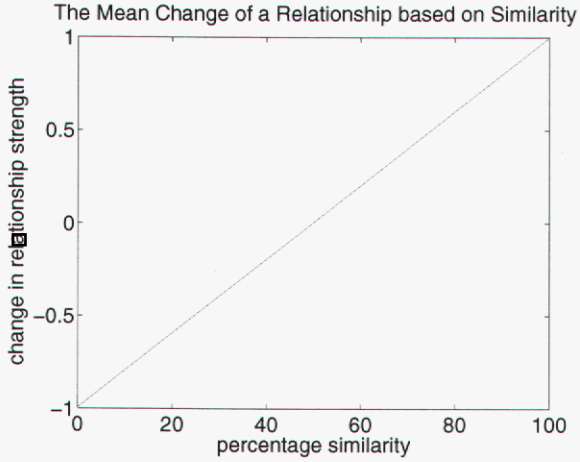

Figure 14: Equation for converting similarity of two agents to the change in their bond strength.

Depending on the similarity and the randomness of relationships formation, the change of the strength of a relationship can result in overall negative relationship strength. Any relationship that has a negative value is removed from the list of relationships.

The relationship capacity imposed on the individual limits the formation of relationships. As a simulation is run, inevitably, individuals reach the set capacity. Subsequent formation of and changes to a relationship results in the reduction of the strength of all existing relationships. Other possibilities such as dropping the weakest links or reducing relationships by a percentage were considered but created strange anomalies. This scheme enables relationships which are not consistently reinforced to die out over time while also removing weak links in a timely manner.

4.2.2 Network

Individual agents belong to social networks which vary dynamically from day to day. There is a prevalent world network containing all individual agents and smaller networks derived from past interactions and abstract agents. There are five networks within our model: the *world* network (which connects everyone together), the *mosque* network (which connects an individual with other agents attending the same mosque), the *acquaintance* network, the *strong bond* network, and the *clique* network (which captured different levels of relationships between agents). Through varying an agent's interaction with different networks, the types of friendships that form (i.e., within a mosque vs. throughout the world, the number of bonds vs. the strength of the bond) illuminate the underlying dynamics of different social scenarios.

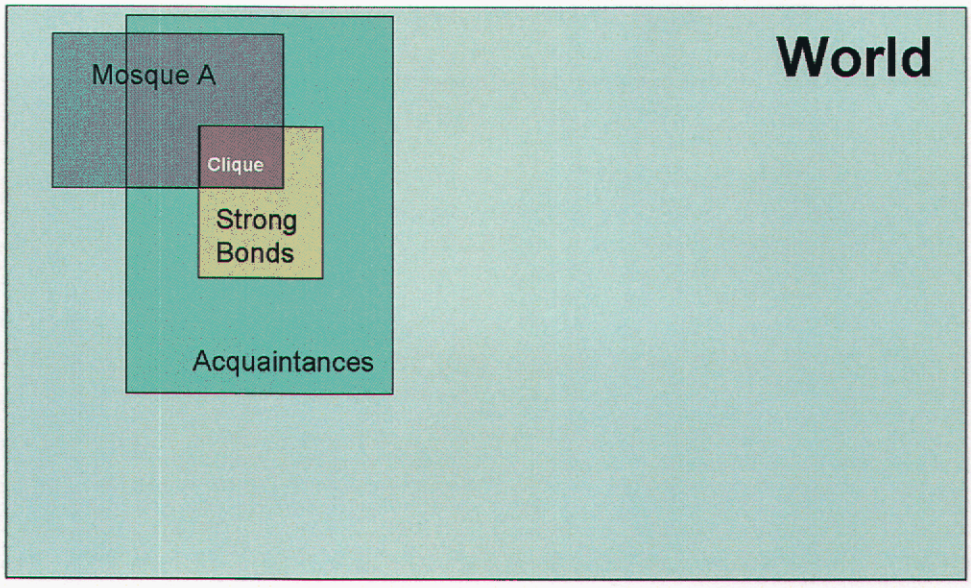

Figure 15: An agent's view of the world through its social networks.

Figure 15 shows an *expatriate*'s view of the world. From the beginning, an *expatriate* is connected to all agents through the *world* network. This enables random interactions to occur between *expatriates* that do not know each other, representing the chance meetings that occur throughout an individual's life. The *mosque* network is another network that enables random interactions between *expatriates* that do not know each other. This network is distinct from the *world* network because it is limited to the specific mosque an individual is attending on that particular day. Thus, an individual can gain or lose the *mosque* network depending on its membership decision. An individual is directly connected to all other individuals within the attended mosque. The *acquaintance*, *strong bonds*, and *clique* networks will be described in Section 4.2.3 in terms of how they assist the formation of *cliques*.

The end user is allowed to specify the probability of interacting within each network. If an individual does not belong to one of the networks during a time step, the probability of the remaining networks are normalized. This results in a bias towards the *world* and *mosque* network in the beginning of a simulation.

4.2.3 Clique Formations

The *acquaintance*, *strong bonds*, and *clique* networks are built up by the random interactions that occur through the *world* and *mosque* networks. The *acquaintance* network represents an individual's acquaintances. This network can specify a threshold to specify how strong the strength of a relationship needs to be in order to be considered an acquaintance. By creating a distinct network for acquaintances, it enables the individual to adjust its interactions to represent the social behavior of individuals seeking out others that they have meet and have felt a connection with. The *strong bonds* network represents the bonds between friends. As individuals continue to interact with others, some acquaintances turn into friends. A distinct *strong bonds* network is used again to represent the different social behavior of individuals towards their friends. Presumably, individuals will seek to interact with friends more often than acquaintances.

Cliques are the next level of interactions where once formed, an individual will have a close knit set of friends which are all friends with one another. Often in cliques, individuals have a tendency to be very similar and to become more similar through their constant interaction. *Cliques* are unique in that they are also an abstraction, capturing this tendency through influencing the member's disgruntlement.

Because *cliques* are dynamic entities where membership is fluid, we have used the *strong bonds* network to derive *cliques* on a day-to-day basis. The bonds in the *strong bonds* network are examined at the conclusion of each day for individuals who have many of the same neighbors. We used a weak definition of a clique to facilitate the formation of fully connected cliques. As in real social interactions, friends of friends often become friends on the strength of existing bonds due to group activities.

5 Simulation results

While we attempted to keep the model simple, the final formulation required 58 adjustable parameters, all of which required values that were not available. The list of parameters along with their descriptions can be found in Appendix X and Y. We initialized the simulation with no social networks (no relationships) and no mosque affiliations. Without actual demographics or social networks, we felt this was the most prudent approach for the short-term.

5.1 Base Case Analysis

We first tuned the input parameters so that the model output mimicked the overall Sageman pipeline, including a plausible number of Jihadi Converts. The Base Case parameters are listed in Appendix Y. Individual agents that enlisted via the Bridge were considered Jihadi Converts for the purposes of this report. We omitted the final step wherein the cliques are further screened at the Afghanistan camps. Sageman estimates that only 10-15% of those entering a camp are eventually admitted to the GSJ. The Base Case parameters were not the only set that could describe the pipeline qualitative; they were simply a starting point.

The output of the model is shown in Figure 16. The Base Case run was set at 600 time steps, or approximately two years. The establishment of "Friends", i.e. – two agents with a strong bond between them, developed slowly and peaked at ~5/Agent and $t = 500$. As the relationships developed, Cliques also began forming starting at $t = 150$. A strong growth spurt emerged between $t = 200$ and 300. We were not ale to determine the cause of this spurt. Concurrent with the emergence of Cliques, Extreme Cliques (highly Disgruntled Cliques) also began to develop providing a population ripe for enlistment. As each of these cliques serendipitously met the Bridge, they were able to enlist only if they met the approval of the Bridge. The rate of growth appeared non-linear in that most of the converts appeared between $t = 400$ to 600, although there was a sizeable population of Extreme Cliques by $t = 300$. The cause for this induction period was unclear. The progression from isolated individual to a converted jihad as postulated by Sageman is therefore captured in this Base Case.

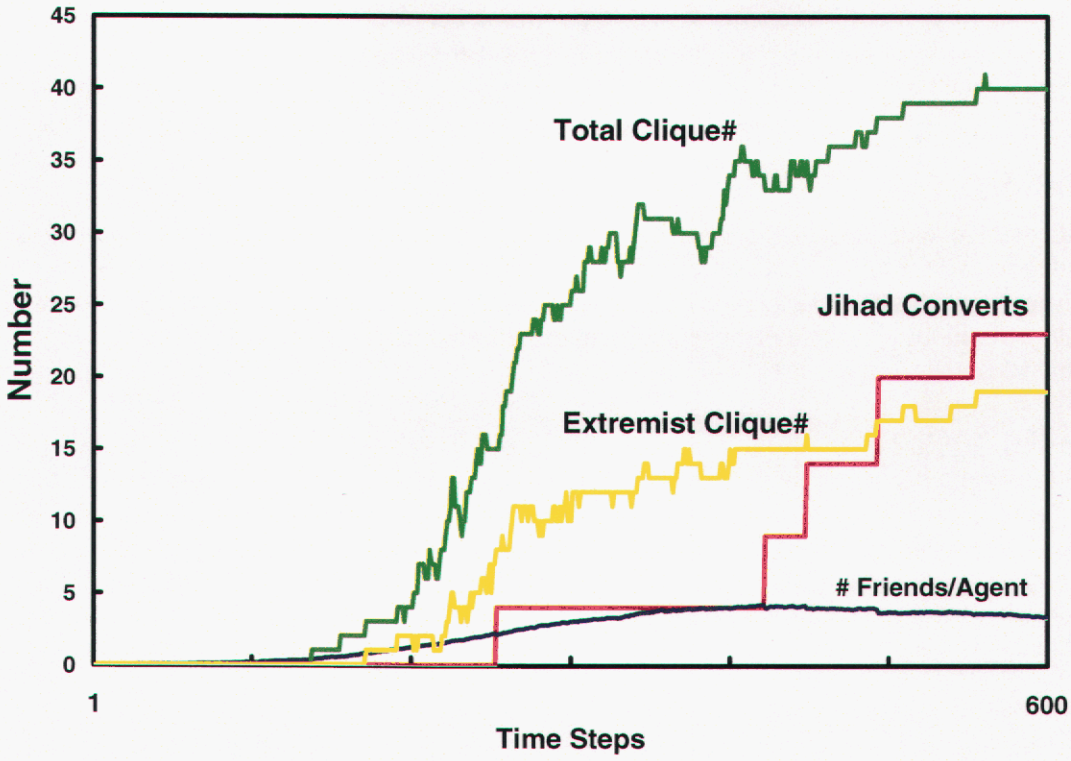

Figure 16: Base Case illustration of the development of Cliques and Jihad Converts.

5.2 Social Network Dynamics

Unique to Seldon is algorithm for generating social networks through growth of variable-strength bonds between individual agents. Figure 17 shows the output from the Base Case of the "Friends" distribution at three different times, t = 160, 300, and 500. There was no distribution at t = 0 since none of the agents started with any "Friends". At t = 160, the strong bonds were just beginning to form between individual agents, with most in dyads and triads. This follows a power-law distribution that has been indicated for large social networks and often called the "small-world effect" [25],[33], although without supporting sociological data.

The power-law distribution quickly evolved into an interesting hump-backed shape by t = 300 and then gradually became a normal distribution by t = 600. There have been sparingly few studies of large social networks (N > 100) [6],[19] because of the difficulties involved in collecting such data. This naturally adds to the challenge of modeling network dynamics. As an interesting exercise, we compared the Seldon distribution taken at midstream (t = 300) to that from a study by researcher, James Coleman [6], and shown in Figure 18. Coleman investigated the social networks of students in ten high schools across the U.S. in both rural and urban communities. The distribution shown in Figure 18 is the average of the ten.

In short, the two distributions are very similar. We are not implying that a cohort of U.S. high school is representative of Arab men expatriates. On the other hand, the general agreement in distribution suggests that the Seldon algorithm may indeed be a plausible representation.

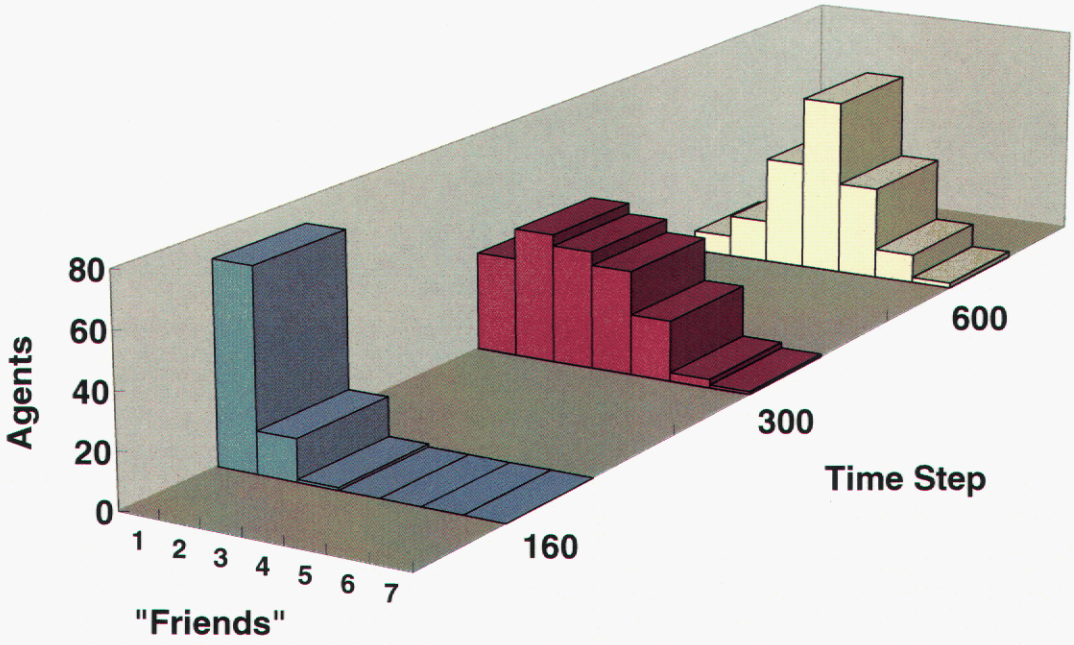

Figure 17: Progression of the "Friends" social network in the Base Case.

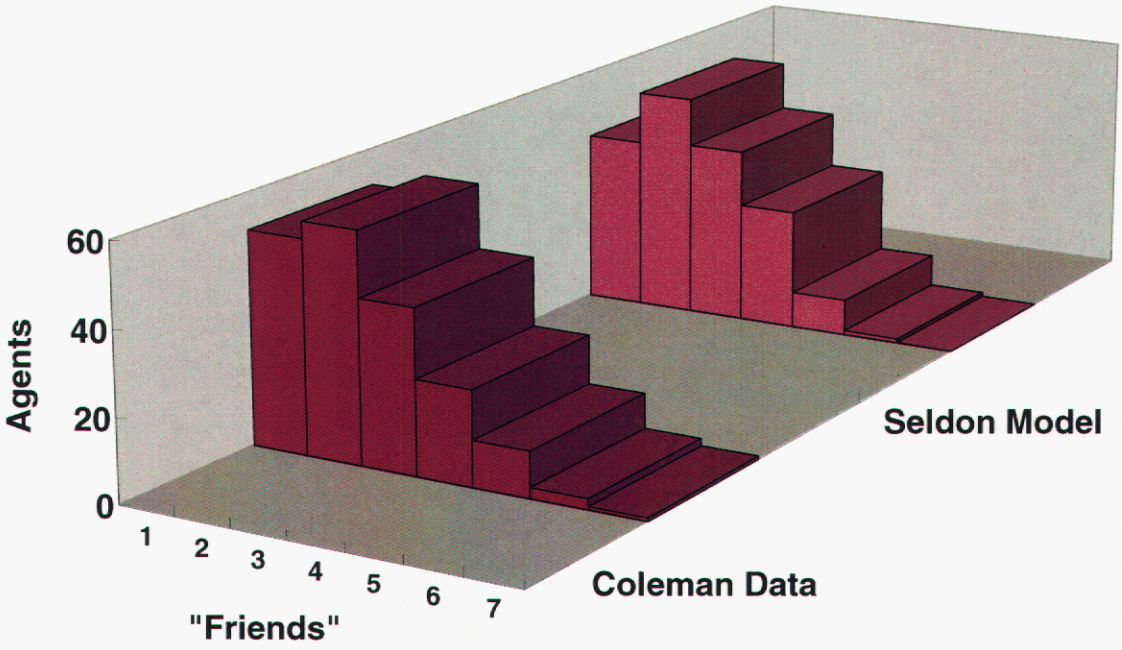

Figure 18 Comparison of Seldon and Coleman [6] social network distributions

5.3 Population Polarization

One of the most interesting outputs from the Base Case run was the strong polarization of Disgruntlement, as shown in Figure 19. Starting with an initial normal distribution, the population Disgruntlement slowly diverged into two subpopulations, high and low Disgruntlement.

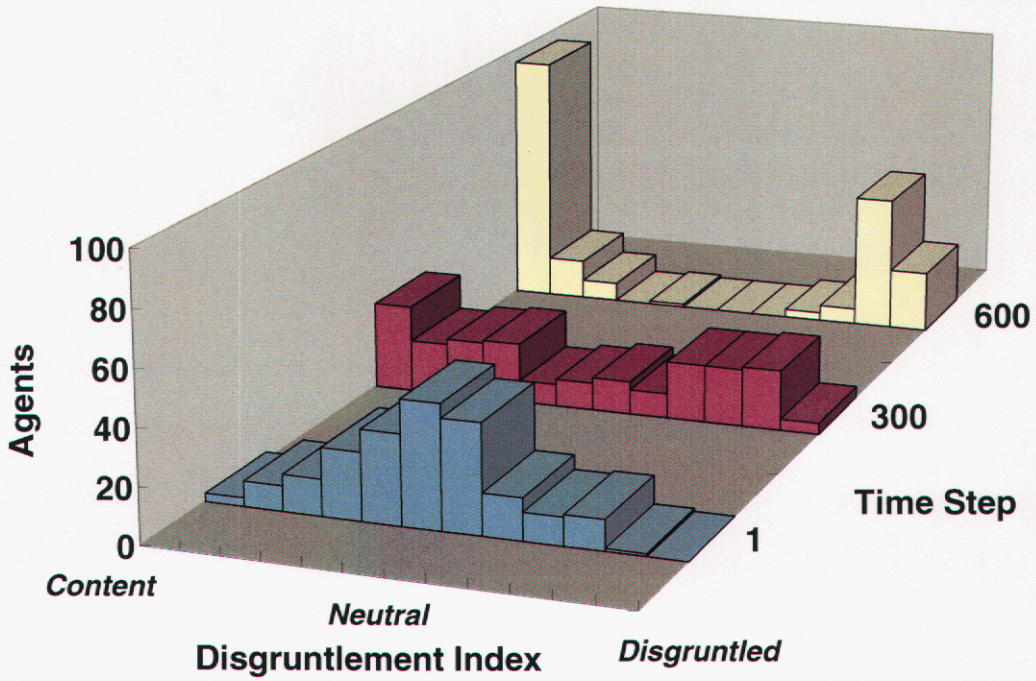

Figure 19: Progression and polarization of Disgruntlement in Base Case

The polarization originated directly from the implementation of the Emotion Contagion, by which two similar agents amplify each other's Disgruntlement. Figure 20 shows the Base Case simulation without the Emotion Contagion. Is this unexpected output an aberration from an inaccurate model, or does these phenomenon actually occur? Few data exist to help answer this question. Conversations with Sageman indicate that the polarization is almost a certainty in wartime and other times of high socio-emotional stress. However, this may not have been the case for the Arab expatriates. Regardless, understanding the process of transferring emotion is critical to the output and needs to be better understood.

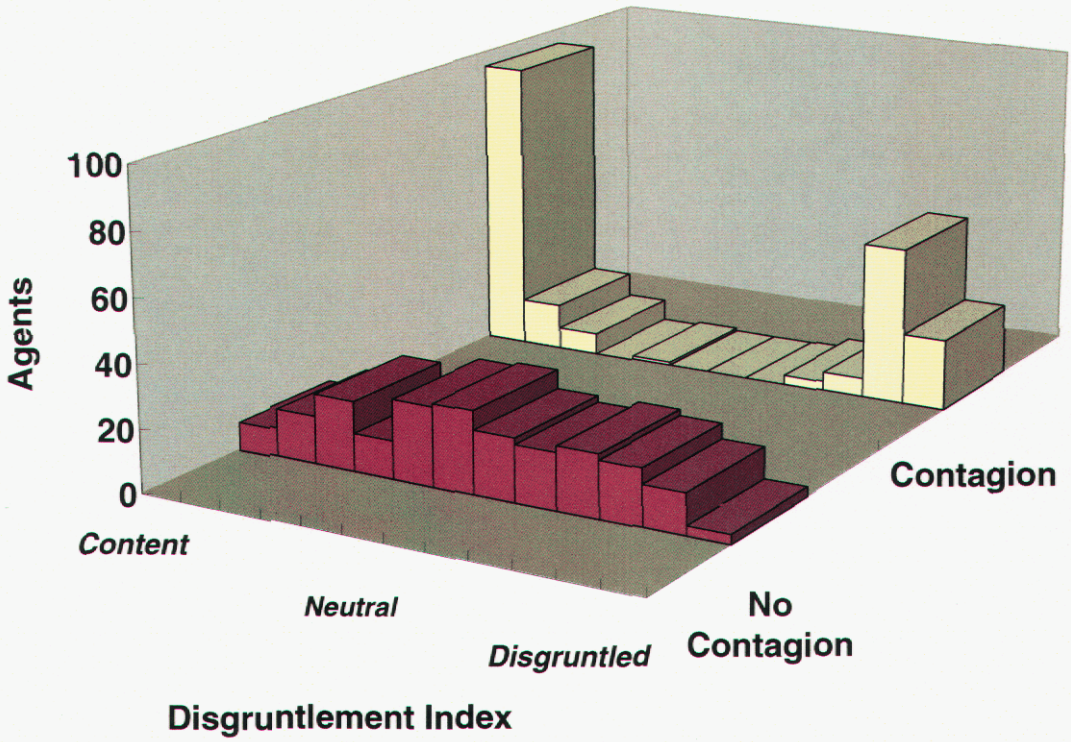

Figure 20: Influence of Emotion Contagion on Disgruntlement

5.4 Testing of Interventions

Several terrorist mitigation interventions were tested on Seldon and the results are summarized in Figure 21. In all cases, the Base Case was used for comparison. The most prominent intervention was making the City Agent more tolerant of immigrants. This was more a factor of how the model was formulated rather than any new insight from Seldon. However, the actual mechanism by which the City's intolerance gets transferred to the individual agent is poorly understood and needs to be better explored.

As a potential intervention, we tested closing down mosques. The output from Seldon, however, suggests that the effect might be minimal unless the actual Jihadi Mosque was luckily selected. However, identifying the problem Mosque in advance would be extremely challenging. In any case, the individual agents, who would otherwise have attended the closed Mosque, simply go to an open Mosque as the next best option. We should note, however, that when we extend the run from $t = 600$ to 900, we observed an marked increase in Jihadi Converts of 2X over the Base Case. The increase can be explained by the larger social network within each of the remaining mosques which leads ultimately to more converts. Therefore, Seldon would suggest that closing Mosques would appear to be ineffective and also potentially damaging in the long-run.

We then explored making agents generally less Disgruntled (more content), by shifting the entire Disgruntlement distribution (see Figure 22) downward. The result was that the number of initial Disgruntled agents ($D > 0$) decreased from 50 to 16%. A comparison of final Disgruntlement distributions is shown in Figure 23. While the number of extremists (high Disgruntlement) decreased by 40%, the actual number of Jihadi Converts remained essentially constant. We interpret this result as suggesting the tail of the distribution is extremely important. The Seldon Model therefore suggests that policies and interventions aimed unfocused at the general population may not be very effective.

Finally, we tested several other interventions that targeted the clique formation processes: (1) increase acquaintance barrier, (2) limit relationships, (3) reduce acquaintance interactions, and (4) increase friendship barrier. All of these interventions reduced the final number of Jihadi Converts, but require some explanation. "Increase acquaintance barrier" targets the relationship strength threshold for two agents to becoming acquaintances. Raising this barrier would require more interactions to establish an acquaintance. "Limit relationships" decreases the total relationship strength that an agent possesses and therefore limits the connectivity and strength of their social network. "Reduce acquaintance interactions" shifts the agent interactions away from the acquaintance network and toward another of the networks (City, Mosque, "Friend", or Clique). With fewer acquaintance interactions, developing "Friends" or Cliques becomes much more challenging. Finally, "increase friendship barrier" will make the threshold higher for becoming "Friends". Two agents would therefore have to interact more often cumulatively before they became friends.

While these interventions may point to the type of interventions that might be useful, Seldon does not specify how these interventions would be undertaken. For instance, "increase friendship barrier" may be effected by adding enemy agents that intended to harm the expatriate agents, or by making all agents more suspicious of their acquaintances. At this stage of development, this is a level of granularity not yet considered.

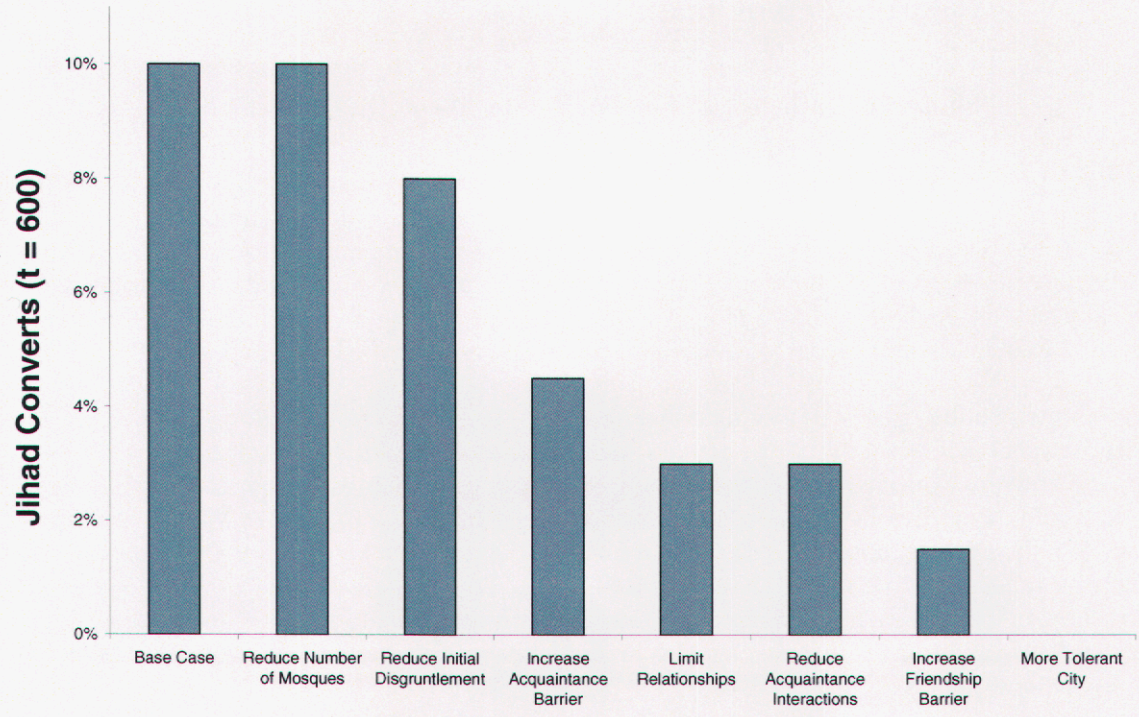

Figure 21: Testing intervention strategies. Δ = 40-50% for parameters at t = 600

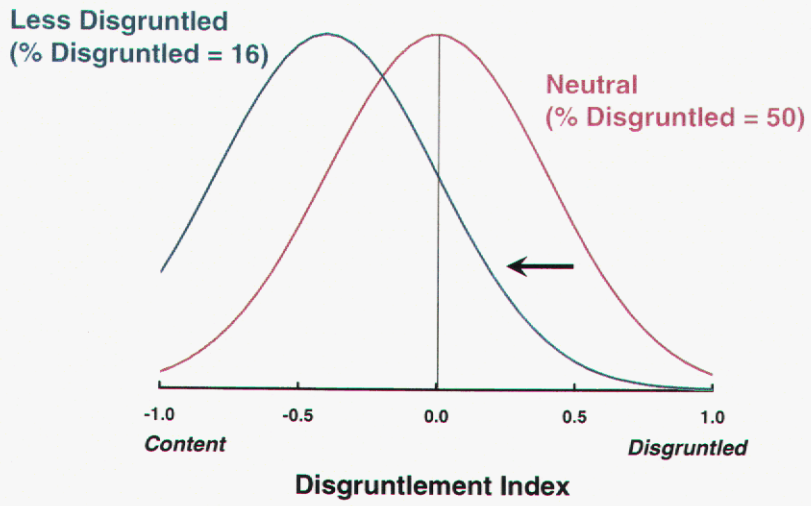

Figure 22: Decreasing the initial Disgruntlement of the agent population.

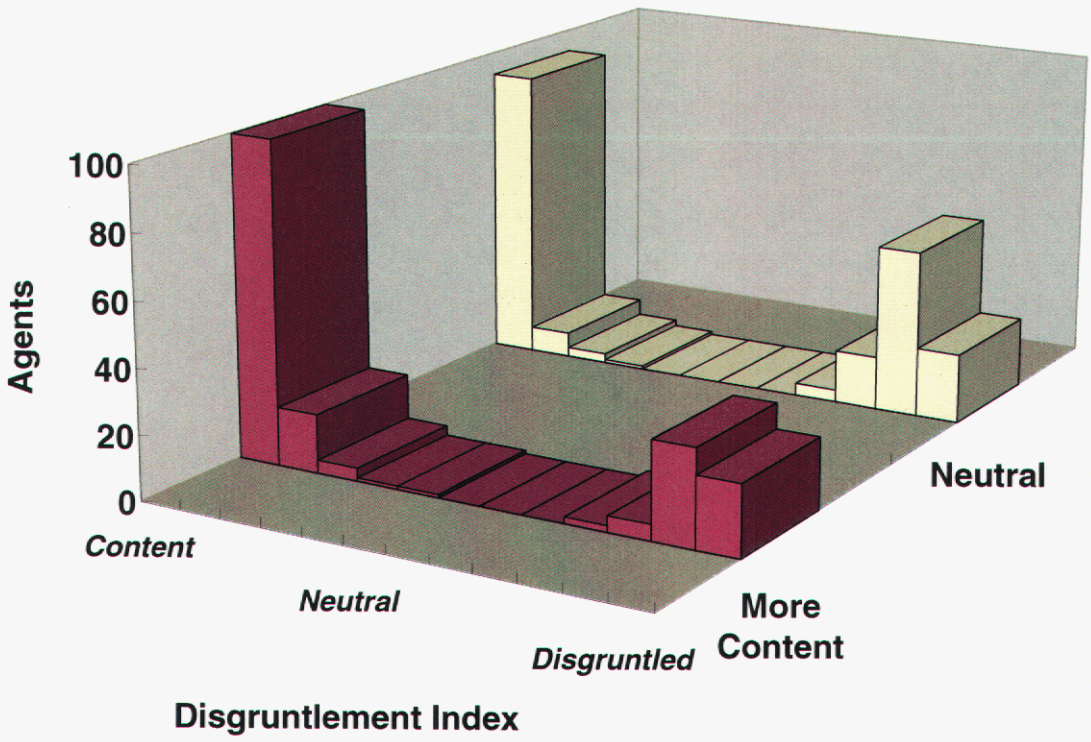

Figure 23: Effect of decreasing initial Disgruntlement on Jihadi Converts.

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6 Model Modifications

6.1 Importance of Kinship to Terrorist Model

The importance of kinship for self-definition and social organization in the Middle East cannot be underrated. We have not included it in the current version of SELDON as its instantiation in the societies in question make its implementation more of a challenge than it would be if we were modeling a western society.

Patai [26] points out that "Familism, that is the view that the family is central in practically all aspects of life, ...even today wields considerable power over Arab thought and sentiment." [26]The unit of importance is more than the nuclear family (it is the extended family); descent is reckoned through the male line (it is patrilineal); newlywed couples live with the husband's family (it is patrilocal); and the preferred marriage is with the father's brother's daughter, that is, within the same patrilineage (it is endogamous) [26], [29].

The importance of family in Islam is reflected in many ways, not the least of which is the large religious schism between the Sunni and Shi'ite groups which is focuses around the importance of descent from Mohammad and 'Ali and the religious and political power that such decendants may have. The *shari'a*, or body of Islamic law, deals extensively with the role of the family in arenas such as marriage.

The family also serves as a situationally defined social organizing principle in the Middle East. The peculiar nature of this ever-shifting yet family-based organization, is reflected in a proverb quoted by Patani: ""I against my brother; I and my brothers against my cousins; I and my cousins against the world." [26]. This principle of situationally defined alliances was noticed earlier by Evans-Pritchard in his ethnography of Nuer tribesmen ([10]),[3] which introduced the term 'segmentary lineages' into the anthropological literature. T.E. Lawrence had noted the same tendency in his work with the Arabs[20].[4] Rosen, in a more recent study [29], notes that kinship, as well as other types of structures for defining individual identity, are situationally defined among Mahgreb Muslims. An individual selects among a suite of possible identities by negotiating a definition of a social situation and choosing the appropriate identity.

The notion of the existential validity of categories of social identification (one is always an 'uncle' no matter what the situation) is quite foreign to this environment. This makes the challenge of incorporating kinship into SELDON as a frame for individual identity more difficult. At the same time, it underscores the importance of social context for social identity, and highlights the dislocation an expatriate (such as the individual agents in the SELDON model) might feel.

6.2 Improved Mosque Attendance Dynamics

Currently, mosque attendance is based on two factors: an individual's isolation and stickiness towards the mosque. The resulting simulation runs have brought to light the weakness of the formulation describe in Section 6.2. There are two anomalies that occur: isolated agents can become stuck to a mosque and a

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[3] "The political system is an expanding series of opposed segments from the relations within the smallest tribal section to intertribal and foreign relations, for opposition between segments of the smallest section seems to us to be of the same structural character as the opposition between a tribe and its...neighbours, though the form of its expression differs" [9].

[4] "..which might have led to anarchy, if they had not made more stringent the family tie, and the bonds of kin-responsibility. But this entailed a negation of central power...The Semite's idea of nationality was the independence of clans and villages, and their ideal of national union was episodic combined resistance to an intruder." [17]

clique can form across different mosques. While both of these anomalies can readily occur in reality, it seems unlikely that this would be the predominate social model.

In further discussions with Sageman, we have determined another factor which contributes to mosque attendance: friendships. An individual's choice in a mosque should be influenced by its friend's choice. This reflects the social behavior of individuals inviting their friends to participate in their activities. While friendships currently allow the affect convergence between the two friends, it should also pull friends to the same mosque.

In the current model, only the stickiness of the attending mosque is maintained for each individual. Rather, an agent's "stickiness" to all mosques can be transformed into relationships between the agent and the mosque, using the same dynamics established for relationships between two individual agents. The agents can then be repelled away from mosques that are dissimilar resulting in less isolated agents becoming stuck to a mosque. Interactions between two individual agents can also modify the relationships between the agents and their respective mosques.

6.3 Variations in Individual Agent Types

Seldon was populated with one type of individual agents representing young Expatriated Arab men, each with an identical set of behavior rules. Although there was a realization that multiple agent types would be valuable, the scope of the project did not allow for this development. Our recommendations for variations in individual agents are twofold.

First, we recommend adding more variations to the agent population of Arab expatriates. As place holders, three attributes were provided these agents, but they did not serve any meaningful function other than for homophily comparisons. In future research, we suggest endowing the agents with a set of real attributes that influence the behavior rules. For example, an attribute capturing introversion/extroversion would affect an agent's interest in interaction with other agents and making relationships. This addition would enable us to explore the importance of shyness on the propensity to join terrorists. Another example would be adding a hierarchical attribute, designating a social or organizational standing like charismatic leader. This attribute could significantly affect the interactions by adding asymmetry factor.

Second, we would also recommend adding different types of individual agents: women, native agents, and family members. Each provides influences that can enhance or retard the processes for producing converts.

6.4 Calibration of Social Sub-models

The input parameters were tuned so that the model output mimicked the overall Sageman pipeline, including a plausible number of Jihadi Converts. Individual agents enlisting via the Bridge are considered Jihadi converted for this report. The current simulation also omitted a final step in the model where cliques are trained in Afghanistan camps and further evaluated. Sageman estimates that only 10-15% of those joining a camp are eventually admitted to the GSJ. The Base Case parameters are not the only set that would suffice for this qualitative test, but they simply represent a reasonable starting point. The Base Case parameters are listed in Appendix Y.

6.5 More Complex Bridge

At present, the *bridge* works simply as a conduit for the *expatriates* to the terrorist camps. Inevitably, given enough time, all *expatriates* who belong to a disgruntled *clique* enlist in the terrorist camps. In fact, with a reasonable set of model parameters, there is almost an instant conversion of disgruntled cliques into enlisted cells, within a few time steps.

Discussions with Sageman have lead to the revelation of a complex underlying dynamic for expatriate conversion. It isn't enough that an *expatriate* belongs to a disgruntled *clique*. Rather it must be familiar with the individual and approve of its past behavior and current standing within the community. Along with that, its past interactions with particular individuals result in a shared personal history which affects a *bridge*'s decision to enlist the *clique*.

7 Future Concerns for Computational Agent Development

Research and development in the social computational agent-based community represents one of the most multi-disciplinary collections of research concepts integrated into a unique solution for exploring segments of society in a simulated world. The future of this research is innately linked to increased interactions between computational modeling, agent-based modeling, sociology, economics, and psychology communities. Each of these groups represents a piece of the larger system development thus providing analysis tools to study the evolving interactions and behaviors between different collections of socially diverse individuals. While this vision will require 15-20 years of continuous development, important foundational concepts are being explored by different projects on a yearly basis.

While there are several unknowns at this stage of development we believe that the field will require true advancements in underlying core technology to direct the field to explore more innovative paths. A major concern in this core development is gauging the *degree of granularity* needed to represent the individual agents in the model. This question is not easily answered and will results in numerous arguments both external and internal to the multi-disciplinary teams that influence the development of these models. The lack of an answer to this question directly influences the level of representation of the individual entities in the general model. Including the internal details (e.g., agent gender, economic status) of each individual agent, their social interaction/relationships, and how they influence each other.

Other unknown issues include more complex environmental representation that makes the agent more aware of its surroundings and environmental situations (e.g., location in the town). Currently most systems do not incorporate any *geospatial knowledge* into their models treating the physical world more like an empty space where their agents reside. What importance would the incorporation of this knowledge bring to current development? It would directly influence issues of agent interactions and relationships by incorporating the feasibility of interaction to a given situation.

The lack of *advanced decision-making* is a core complexity that prohibits current models from achieving any relevance beyond behaviors based on structured rule-sets. While many agree that advanced decision-making is needed the approaches and degree of incorporation of these concepts are unknown at this time. Potential solutions range from the integration of simple cognitive components to complete cognitive models to improve the overall complexity of the computational agent system. The future of computational agent-based social models is being driven by many different factors including recent concerns in using these systems to better understand why pockets of society respond in different manners to situations that have little affect in other social pockets.

8 Conclusions

The Seldon (a.k.a. DICTUM) toolkit was initially established in FY03 as an organizational tool used to study gang recruitment and how society might influence the individuals being targeted by these groups. In FY04 the initial toolkit was expanded based on some initial experimentation and refocusing of the project to model terrorist recruitment based on the work of Marc Sageman. While the underlying organization concepts of Seldon were used, new social concepts and interaction models where added to closely reflect how terrorist recruitment differs from the initial gang model. Modifications to the Seldon model included additions for emotional behaviors and multiple levels of social networks. With these new modifications

the terrorist model permitted the user the ability to observe increased relationship development between individual agents from casual meetings to tight group formations based on similar interest. The reoccurring meetings between individual agents was seen as the building of bonds between the agents, thus affecting the influence agents had over each other. The terrorist model also incorporated behavioral issues associated with the happiness of the individual agents and the acceptance of the surrounding society to their presence.

The complete terrorist model permitted the user to adjust 58 different concepts and parameters, thus providing a wider range of possible outcomes based on the initial scenario. The simulation begins with no established relationship or affiliation permitting these aspects to evolve as the simulation progresses. Replication of the simulation is achieved by providing the same random seed to the initial system. While the lack of any demographic information contributed to this generalized initialization approach, Seldon can be extended to read such information from a data file. In its current formation Seldon permits the user to select how the system will be initialized and visually observe the outcome of their parameter selections.

The Seldon toolkit and terrorist model provides a unique capability that incorporates both innovation and cutting edge research into a single software package. Where the innovations permits the developer to capture social norms and mores as part of the simulation in the form of abstract software agents. These agents aided in providing varied levels of granular knowledge representing small, medium, and large societal views. The cutting edge research was part of the desire to represent multiple social networks to explore a richer set of social interactions. While multiple social networks in not a new concept, only a few computational systems attempt to implement this capability. The completion of this project has permitted the team to explore terrorist recruitment and develop a different architectural approach to the computational agent-based community.

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10 APPENDIX Y

Simulation	
number of time steps (days)	600
average number of interactions per day	2.0
Expatriate	
relationship energy capacity	75.0
std. deviation for relationship energy	0.0
similarity threshold for creating a relationship	0.0
(-/-) reinforcement (-2 to 2)	-0.01
(-/-) attraction (-2 to 2)	0.0050
(-/+) reinforcment (-2 to 2)	0.0
(-/+) attraction (-2 to 2)	0.0050
(+/+) reinforcment (-2 to 2)	0.01
(+/+) attraction (-2 to 2)	0.0050
num of expatriates	200
initial Disgruntlement	0.0
std dev on Disgruntlement	0.4
Weighting for three discrete attributes	0.5
Weighting for Disgruntlement	0.5
Bridge	
relationship energy capacity	0.0
std. deviation for relationship energy	0.0
similarity threshold for creating a relationship	100.0
(-/-) reinforcement (-2 to 2)	0.0
(-/-) attraction (-2 to 2)	0.0
(-/+) reinforcment (-2 to 2)	0.0
(-/+) attraction (-2 to 2)	0.0
(+/+) reinforcment (-2 to 2)	0.0
(+/+) attraction (-2 to 2)	0.0
num of bridges	1
probability of converting expatriates	0.02
Society	
changes to agent's Disgruntlement (-2 to 2)	0.0
std. deviation of change (absolute)	0.05
probability of outgoing expatriate to interact with society (0 to 1)	1.0
probability of shy expatriate to interact with society (0 to 1)	1.0
Mosque	
changes to agent's Disgruntlement (-2 to 2)	0.0
number of neutral mosques	4
number of jihadi mosques	1
Disgruntlement of neutral mosques (-1 to 1)	0.1
Disgruntlement of jihadi mosques (-1 to 1)	-1.0
stickiness weight of mosque's disgruntlement	0.075

stickiness weight of the similarity of mosque's disgruntlement	0.1
stickiness weight of the similarity of the members' disgruntlement	0.025
stickiness weight of the similarity of members' attributes	0.075
threshold for being stuck in a mosque	1.0
Clique	
changes to agent's Disgruntlement (-2 to 2)	0.01
threshold to consider joining the Jihad	-0.5
Strong Bonds	
strength of bond threshold	10.0
Acquaintances	
strength of bond threshold	0.0
Population	
outgoing & attr 0 (true) & attr 1 (true) &	0.125
shy & attr 0 (true) & attr 1 (true) &	0.125
outgoing & attr 0 (false) & attr 1 (true) &	0.125
shy & attr 0 (false) & attr 1 (true) &	0.125
outgoing & attr 0 (true) & attr 1 (false) &	0.125
shy & attr 0 (true) & attr 1 (false) &	0.125
outgoing & attr 0 (false) & attr 1 (false) &	0.125
shy & attr 0 (false) & attr 1 (false) &	0.125
Interactions	
World	0.01
Mosque	0.49
Strong Bonds	0.01
Clique	0.01
Acquaintances	0.48

11 APPENDIX X

Simulation

Number of Time Steps

This is the number of time steps in the simulation. Although we have attempted to select interaction rates that map to daily occurrences, the correspondence to real time is unconfirmed.

Average Number of Interactions per Time Step

This is the average number of individual-individual interactions. This excludes the abstract-individual interactions.

Details: User defines total number of individual-individual interactions per time step. For example: 100 agents with 2 interactions per day specify 200 individual-individual interactions, but not that each individual has exactly 2 interactions. The 200 interactions are randomly chosen, and the actual number of interactions per agent is a distribution.

Use same random seed (True or False)

Many of the model decisions are probabilistic, i.e. - depend on the random number generator. The name "random number generator" is somewhat a misnomer as the generator produces a sequence of random numbers, but needs a starting "seed". If supplied with the one "seed", the random number generator will output the same random number sequence every run. In short, setting this input to "True" while keeping all parameters constant will be produce identical results. Set to "False", the outputs are probabilistic and each subsequent run of the model will produce different results.

Expatriate

The vast majority of individual agents in Seldon are Expatriates, which represent Core Arab males between 18-30 residing in foreign cities.

Relationship Energy Capacity (REC)

Relationship energy is the strength of the bond between two Expatriates. Each individual has a limited Relationship Energy Capacity, or REC, with which to form bonds with other agents. In combination with the Strong Bond Threshold, these two parameters are important for determining the maximum number of strong-bonded relationships per agent.

Example:
User defines REC = 75 and Strong-Bond Threshold = 5. The maximum number of strong bond links would be 75/5, or 15. This also defines the maximum clique size.

Std deviation for relationship energy

During an agent-agent interaction, the change in their relationship energy is determined mostly by the similarity of the agent attributes, but the actual change is probabilistic. Increasing this parameter effectively relaxes the homophily requirement for creating relationships. Identical agents may therefore not form relationships while different agents might actually form relationships.

This is an absolute standard deviation. Keep in mind that the maximum relationship energy change per time step is 1. Set this parameter to 0 to make the change in relationship energy absolute, dependent entirely on homophily. Set this parameter to >2, and homophily is no longer considered.

Attitude Convergence

During agent-agent interactions, the agents simultaneously influence each others Disgruntlement (attitude). An agent's Disgruntlement is ranges between -1 and 1, where 0 is neutral. Agents with Disgruntlement < 0 are disgruntled agents, while Disgruntlement > 0 are happy agents. Literature suggests that similar agents, like disgruntled/disgruntled, tend to both amplify their individual Disgruntlement AND converge to a common Disgruntlement between the two.

The nomenclature used to define the interactions indicates the Disgruntlement sign of the agents. For example, a (-/-) interaction is between two disgruntled agents with Disgruntlement < 0.

(-/-) Reinforcement (-2 to 2)

The Disgruntlement (D) of both agents is incremented by this value during an interaction. Example: Agent 1 (D_1 = -0.30) and Agent 2 (D_2 = -0.60) interact with a Reinforcement of -0.02. The new values are D_1 = -0.32 and D_2 = -0.62.

(-/-) Attraction (-2 to 2)

The Disgruntlement of both agents converge to their average both this increment. Agent 1 (D_1 = -0.30) and Agent 2 (D_2 = -0.60) interact with an Attraction of 0.01. The new values are D_1 = -0.31 and D_2 = -0.59, as the two converge to an average of 0.45.

(-/+) Reinforcement (-2 to 2)

See above

(-/+) Attraction (-2 to 2)

See above

(+/+) Reinforcement (-2 to 2)

See above

(+/+) Attraction (-2 to 2)

See above

Number of Expatriates

Number of individual agents (Expatriates) in simulation. Bridges not counted.

Initial Disgruntlement

Disgruntlement ranges from -1 (very disgruntled) to 1 (very gruntled), with 0 being neutral. All Expatriates have the same disgruntlement initially.

Weighting for three discrete attributes (W_D)

The two weighting parameters, W_D and W_G, are used to calculate a similarity index (I_{sim}), which is measure of two Expatriates similarity and is calculated by comparing their attributes. Each agent possesses four attributes in Seldon. The first three discrete attributes are static and binary (1 or 0). The first attribute has

been designated for outgoing (1) or shy (0). The second and third attributes are placeholders for later model versions which will allow descriptors such as affiliation with specific networks, position in certain kin, etc. The fourth attribute is Disgruntlement (D). Two agents sharing many similar attribute values would have a high I_{sim} and therefore tend to form a bond, and vice versa.

The "Weighting" parameters for discrete attributes (W_D) and Disgruntlement (W_G) are simply user defined parameters to balance the importance of discrete attributes versus Disgruntlement. Note that the parameters are set relative to each other and absolutely.

Example
User sets $W_D = 0.25$ and $= W_G = 0.5$. In this case, Disgruntlement is twice as important as the other three attributes, cumulatively, for comparing the similarity between agents. Moreover, the maximum change in bond strength per interaction is $0.75 = 0.25 + 0.5$. Agent A (111, $D = 1$) and Agent B(000, $D = -1$) have a similarity index of $I_{sim} = 0$. Agent A (111, $D = 1$) and Agent C(111, $D = 1$) have a similarity index of $I_{sim} = 0.75$. Intermediate similarities are linearly scaled.

Weighting for Disgruntlement (W_G)

See above.

Bridge

Bridge is the second type of individual agent who is a Jihad agent without any relationships, who is currently being forced to attend a Jihadi mosque. There is no transfer of affect between two bridges or between a bridge and an Expatriate. When bridges interact with bridges, nothing changes. When bridges and Expatriates interact, a bridge will convert an Expatriate into a Jihad, if the Expatriate belongs to a clique and the clique's average disgruntlement has crossed a threshold for joining a Jihad. In addition to converting the Expatriate the bridge interacted with, it will convert all the members of its clique.

Number of Bridges

Abstractions

Three types of abstract agents: (1) Society, (2) Mosque, and (3) Clique.

**********Society**********

Each time step, Expatriates decide whether or not to interact with Society. The decision is probabilistic and depends on the Expatriate's attribute of either shy (1) or outgoing (0). Seldon allows the user to parse the population into these two groups exhibiting different tendencies of interacting with Society.

Changes to Agent's Disgruntlement ($\square_{society}$)

When an Expatriate interacts with Society, the Expatriates' Disgruntlement (D) is changed by $\square_{society}$. Note that Society doesn't change from this interaction.

Example
User sets $\square_{society} = -0.1$. Expatriate with $D = -0.4$ interacts with Society. New Expatriate Disgruntlement is $D = -0.5$. $\square_{society}$ is the average incremental change, with a distribution defined by the next parameter. Recall that $-1 < D < +1$.

Std Deviation of Change ($\square_{society}$)

Rather than Society interactions changing all Expatriates identically, Seldon allows for a normal distribution of influences.

Example

User sets $\square_{society}$ = -0.3 and $\square_{society}$ = 0.2. For interaction with Society, an Expatriate Disgruntlement will change by an average of -0.3, but with a distribution typically between -0.7 and 0.1.

Probability of outgoing Expatriate to interact with Society ($P_{outgoing}$)

$P_{outgoing}$ is the probability that an outgoing Expatriate interacts with Society each time step.

Example

User sets $P_{outgoing}$ = 0.9. The outgoing Expatriate will interact with Society 90% of the time steps.

Probability of shy Expatriate to interact with Society (P_{shy})

Same as previous except for shy Expatriate.

**********Mosque**********

Each time step, Expatriates decide whether or not to attend a mosque, and which one (same one or switch). The choice to attend a mosque is dependent on Expatriate's isolation level, as defined by the number of strong-bonded relationships. Expatriates without any strong-bonded relationships are considered isolated and will automatically attend a mosque. Other Expatriates attend mosques based on "Stickiness" factors delineated below.

Change to Agent's Disgruntlement (Δ_{Mosque})

Each Mosque has a Disgruntlement attribute (D) that remains static throughout the simulation, unlike that of the Expatriates. The Δ_{Mosque} parameter specifies the incremental change to Expatriate's D during Mosque attendance towards the Mosque's Disgruntlement.

Example

User sets Δ_{Mosque} = 0.05. Expatriate with $D_{Expatriate}$ = 0.2 attends Mosque with D_{Mosque} = -1. The Expatriate's Disgruntlement subsequently changes to $D_{Expatriate}$ = -0.25 (Expatriate Disgruntlement moves toward that of the Mosque, while the Mosque Disgruntlement is unchanged).

Number of Neutral Mosques

Number of Jihadi Mosques

Stickiness Weight of Mosque Disgruntlement (S_1)

Four factors define whether an Expatriate stays in the same mosque: (1) Mosque Disgruntlement – S_1, (2) Similarity to Mosque Disgruntlement – S_2, (3) Similarity to co-attending Expatriates' Disgruntlement – S_3, and (4) Similarity to co-attending Expatriates attributes – S_4. These parameters allow for the user to specify the relative importance of these four factors. The sum of an Expatriate's "stickiness weights" represents the maximum probability that it attends the same mosque the next time step.

Example
User sets $S_1 = 0.05$, $S_2 = 0.01$, $S_3 = 0.02$, $S_4 = 0.10$. The maximum probability that an Expatriate stays in the same mosque each time step is 0.18 (18%) = 0.05 + 0.01 + 0.02 + 0.10. Naturally, the Expatriate similarity to the other Expatriates and the Mosque itself (comparing attributes and Disgruntlement) will define the actual probability.

The Mosque Disgruntlement, S_1, instantiates the observation that Jihadi Mosques, by their nature, attract and retain Expatriates better than Neutral Mosques. This factor is completely independent of the Expatriates themselves. All other stickiness factors rely on the similarity of the Expatriates to the Mosque and each other.

Stickiness Weight of the Similarity of Mosque Disgruntlement (S_2)

This parameter is dependent on the similarity between the Expatriate's and Mosque's Disgruntlement. The maximum is achieved when $D_{\text{Expatriate}} = D_{\text{Mosque}}$. In short, a disgruntled Expatriate is more likely to stay in a Jihadi Mosque.

Stickiness Weight of the Similarity of Members' Disgruntlement (S_3)

This parameter is dependent on the similarity between the Expatriate's Disgruntlement and that of its fellow attendees (average). The maximum is achieved when $D_{\text{Expatriate}} = D_{\text{Ave Members}}$. An Expatriate is therefore more likely to stay in a mosque if the other members share same disgruntlement level.

Stickiness Weight of the Similarity of Members' Attribute (S_4)

Same as above except for sharing attributes (homophily).

**********Clique**********

Unlike Society and Mosque, Clique interacts with their members every time step. However, the Clique does not possess an independent Disgruntlement, like Society and Mosque. Rather, the Clique Disgruntlement is simply an average of its members' Disgruntlements.

Change to agent's Disgruntlement (-2 to 2)

Each time step, an Expatriate's Disgruntlement is changed by its interaction with its Clique, if it belongs to one. This parameter increments the Expatriate's Disgruntlement by this many units toward (if >0) the Clique Disgruntlement. In this way, the Clique members gradually converge toward the same Disgruntlement.

Threshold to consider joining the Jihad

A clique has an aggregate disgruntlement, or the average disgruntlement of all of its individual agents. When the clique disgruntlement index crosses below threshold (making an agent more disgruntled than the threshold), the clique is ripe for conversion to jihad. When the disgruntlement level is at this point, any serendipitous contact with a bridge with any of its agents will automatically convert the clique to jihad.

Networks

**********Strong Bonds**********

Strength of bond threshold

User needs to define the bond strength threshold for two Expatriates becoming strong-bonded. Sharing a strong bond requires both agents to view each other as more than an acquaintance. Keep in mind the Relationship Energy Capacity (REC) and the average range of relationship bond changes (-1 to 1) when setting this threshold.

**********Acquaintances**********

Strength of bond threshold

Same as above, except that acquaintances are a class relationship whose strength is less than that of "strong-bonded"

Population

This tab allows the user to distribute the Expatriates among 8 types, based on three binary attributes: 000, 100, 110, 111, 001, 011, 101, and 010. The first attribute is assigned to designate an Expatriate as either outgoing (1) or shy (0).

Interactions

Under the "Simulation" Tab, the user defines the average number of interactions per agent. Under the "Interactions" Tab, the user defines the probability that the interactions are between agents who share each of the five different networks.

Distribution:

5	MS9217	Ben Wu	16000
1	MS0839	Gerry Yonas	16000
1	MS0839	Tim Moy	16000
1	MS0839	Jessica Turnley	16000
1	MS0839	Curtis Johnson	16000
1	MS0839	Judy Moore	16000
1	MS0839	John Whitley	16000
1	MS0839	Rick Craft	16000
1	MS0839	Nancy Hayden	16000
1	MS0839	Tom Karas	16000
1	MS0839	Peter Merkle	16000
1	MS0839	Ken Miller	16000
1	MS0839	Patricia Gingrich	16000
1	MS1188	Ann Speed	12335
1	MS1188	Mike Bernard	15311
1	MS1109	Rich Pryor	09216
1	MS0318	Dianne Barton	09209
1	MS0127	Bob Floran	12111
1	MS9003	Ken Washington	08900
1	MS9003	James Handrock	08960
1	MS9003	Chuck Hartwig	08940
1	MS9011	Barry Hess	08941
1	MS9037	Jim Berry	08947
1	MS9158	Mike Koszykowski	08961
1	MS9158	Mitch Sukalski	08961
1	MS9159	Steve Thomas	08962
1	MS9152	Jerry Friesen	08963
1	MS9159	Mike Hardwick	08964
1	MS1170	Russell Skocypec	15300
1	MS1188	John Wagner	15311
1	MS1188	Chris Forsythe	15311
1	MS1188	Steve Tucker	15311
2	MS9158	Nina Berry	08961
1	MS9158	Teresa Ko	08961
3	MS9018	Central Technical Files	8945-1
1	MS0899	Technical Library	09616
1	MS9021	Classification Office, 8511 for Technical Library, MS 0899, 9616 DOE/OSTI via URL	
1	MS0323	D. Chavez, LDRD Office	1011

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