Athena Analyst's Guide

Athena S&RO Simulation, V1

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1. INTRODUCTION

This document presents the models and related constructs implemented in version 1 of the Athena Stability & Recovery Operations (S&RO) Simulation. The models are described in sufficient detail to allow implementation; the implementation itself is not in the scope of this document.

1.1 Overview

The Athena simulation is a decision support tool designed to allow a skilled analyst to consider the unintended consequences of various courses of action that might be taken during Stability & Recovery Operations. Athena is an outgrowth of the Joint Non-lethal Effects Model (JNEM), but includes many new models. In addition, where JNEM is a federated simulation, Athena is a stand-alone single-user application.

1.2 Other Documents

Documentation on using Athena may be found in the on-line help; invoke the Athena Simulation, and select Help Contents from the Help menu. Additional documentation may be found in the "docs" directory of the Athena build tree; open "docs/index.html" in a web browser, and follow the links. The documentation is included with the installed software. Documentation can also be obtained directly from the Athena project; contact `William.H.Duquette@jpl.nasa.gov`.

Documentation in the "docs" directory includes:

Athena Rules

This document describes the events and situations (drivers) that affect group attitudes, and the Driver Assessment Model (DAM) rule sets that assess attitude change.

Mars Analyst's Guide

Athena is built upon a software infrastructure layer called Mars. Models implemented by Mars, including the Generalized Regional Attitude Model (GRAM), are documented in the Mars Analyst's Guide (MAG), which may be found in the Athena documentation tree.

Software Manual Pages

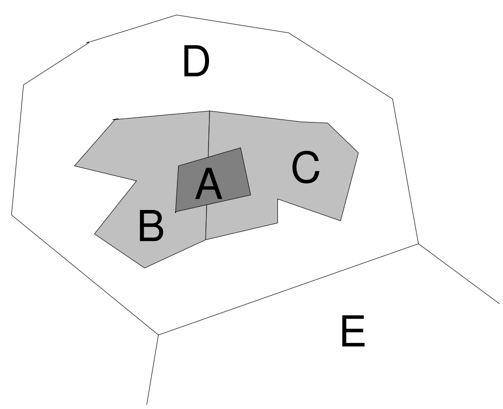
Extensive documentation of the Athena software tools and libraries is included in the software installation set in the form of software “man pages”.

2. ATHENA CONCEPTS

This section gives an overview of Athena and its parts, and of the basic concepts that Athena uses. The discussion is kept to a high level; see sections 3 and following for the detailed models.

2.1 The Athena Playbox

Athena models population dynamics and group activities in a geographical region called the Athena *playbox*. The playbox is divided into areas called *neighborhoods*. Neighborhoods are simply a way of dividing the playbox into a number of reasonably homogeneous areas, and may be of any size: country, province, city, town, zip code, and neighborhood proper. Geographically, neighborhoods are defined as polygons on a map, using some appropriate coordinate system. Neighborhoods may nest, e.g., a city may be a neighborhood within a larger province, and the city may contain several neighborhoods. In the diagram below, A is an urban area surrounded by suburban areas B and C; all three lie within D, a county, which abuts E, another county.



Note that locations within an inner neighborhood are not also part of the outer neighborhood; in the diagram above, D effectively has a hole cut out of it by B and C, and A cuts sections out of both B and C. Consequently, if a neighborhood is completely tiled by nested neighborhoods, it can be omitted as it contains no locations. If D's surface were entirely covered by suburbs, for example, there would be nothing left of D and no reason to define D within Athena.

Although Athena allows neighborhoods that overlap without nesting, like A, it works better in practice if stacked neighborhoods are properly nested. Consequently, the borders of B and C should go around A, rather than A being overlaid on top of them.

In Athena, simulation events take place within neighborhoods, and affect the population of the neighborhoods. An event taking place within a neighborhood can have ripple effects in other neighborhoods; the geographic spread of these ripples depends on how nearby other neighborhoods are presumed to be, not merely geographically but also socially and psychologically. The nearness of one neighborhood to another is an input to Athena called *neighborhood proximity*. There are four proximity levels: *here, near, far,* and *remote*. The above diagram shows proximity to neighborhood A. From A's point of view, A is *here*, B and C are *near* A, and outlying area D is *far* from A. Neighborhood E is *remote*. An event in A would affect A immediately, would likely affect B and C, though to a lesser degree, might affect D to a much lesser degree, and would not affect E at all. Ripple effects in other neighborhoods can also be delayed by an interval, which is an input for each pair of neighborhoods.

2.2 Groups

The people in the playbox are divided into *groups*, of which there are three kinds: civilian groups, force groups, and organization groups.

2.2.1 Civilian Groups

Civilian groups represent the population of the playbox, i.e., the people who actually live in the neighborhoods. This population maybe broken into groups by ethnicity, religion, language, social class, political affiliation, or any other demographic criteria the analyst deems necessary. Civilian groups are similar to the “market segments” used to target advertising: a group is a collection of people who may be assumed to have similar biases, interests, and behaviors due to their demographic similarity.

Athena tracks the civilian population by group and neighborhood; each neighborhood must have a non-zero population of at least one of the civilian groups, and may include representatives of all of the civilian groups. A civilian group residing in a specific neighborhood is referred to as a *neighborhood group*.

In addition to each neighborhood group’s population in its neighborhood, each neighborhood group may also be represented in the Ground model in the form of civilian units. People present in units are referred to as *personnel*, rather than as *population;* however, civilians have the same effect in Athena whether they are represented as personnel or population.

Athena models neighborhood groups in detail, tracking the attitudes of each group in each neighborhood as the group’s members are affected by a variety of events and situations.

2.2.2 Force Groups

Force groups represent military forces, such as the U.S. Army, and other groups whose purpose is to apply force in support of policy. There are five kinds of force group:

- Regular military, e.g., the U.S. Army
- Paramilitary, e.g., SWAT teams and other combat-trained police units
- Police, e.g., normal civilian police
- Irregular military, e.g., militias
- Criminal, e.g., organized crime

The force group type only affects the degree to which a force group's units are able to project force vs. other force groups. Force group personnel are represented as ground units; force units may engage in a wide variety of activities that affect civilian attitudes, and may engage in armed conflict with other force groups.

In addition, a force group may be *uniformed* or *non-uniformed*; this affects the tactics the force group may use. In an S&RO situation, it is assumed that uniformed and non-uniformed forces usually use asymmetric tactics: the uniformed forces (typically regulars, paramilitary, or police) are hunting for cells of non-uniformed forces (typically irregulars), and the non-uniformed forces are attempting to whittle down the uniformed forces by means of IEDs and hit-and-run attacks.

2.2.3 Organization Groups

Organization groups represent organizations that are present in the playbox to help the civilians. There are three kinds: Non-Governmental Organizations (NGOs), International or Inter-Governmental Organizations (IGOs), and Contractors (CTRs). NGOs are groups like the Red Cross or Doctors Without Borders who do humanitarian relief, development, and so forth. IGOs are international organizations like UNESCO. Contractors are commercial firms who are doing development work in the playbox, often but not necessarily working for the Coalition/Government. Organizations may be either local or foreign.

Organization group members are represented in the playbox as ground units; organization units may conduct a variety of activities which affect civilian satisfaction.

Athena tracks the attitudes of each organization group toward working in each neighborhood; a group that is willing to work in a low-risk neighborhood might be unwilling to work in a neighborhood it perceives as high-risk.

2.2.4 Group Force and Neighborhood Security

Both civilian and force groups, and to a much lesser extent organization groups, have the ability and willingness to project and use force. Athena analyzes the balance of forces in each neighborhood, taking into account the populations and personnel present in the neighborhood, the types of each, and the ability of each group and unit type to project force. As the result of this analysis Athena computes the *security* of each group in each neighborhood. A force or organization group’s security in a neighborhood will determine which activities it can perform, if any.

2.3 Modeling Areas

Athena's models are loosely grouped in a number of areas. The models themselves will be described in detail in the body of this document; this section describes each area and the models within it at a high level.

2.3.1 Ground

The most basic area is the Ground model. It includes the neighborhoods, groups, and units, as described above, and also the following specific models:

- Force Analysis
- Unit activities and Activity Situations
- The Athena Attrition Model (AAM)
- Environmental Situations

2.3.2 Demographics

The Demographics model tracks the civilian population of the playbox as civilians are moved from the implicit population of a neighborhood into units and back again, as civilian units are moved around the playbox, and as civilian lives are lost due to collateral damage and other attrition. As currently implemented, the Demographics model could easily be regarded as another part of the Ground model. In the future, however, we expect the Demographics model to track the population by age, sex, and possibly other factors, account for births and natural deaths, and provide inputs (such as the size of the labor forces and consumption of goods) to other Athena models. In light of its future importance, then, it stands alone.

2.3.3 Attitudes

The Attitudes model is responsible for tracking the effects of events and situations (collectively known as *drivers*) on the attitudes of neighborhood and organization groups. Attitudes currently include satisfaction of a group with respect to a variety of concerns, and cooperation of neighborhood groups with force groups.

The engine responsible for tracking attitudes and changes to attitudes is called the Generalized Regional Attitude Model (GRAM); it is documented in great detail in the *Mars Analyst's Guide*, which is delivered with Athena; see section 1.2 .

The *Driver Assessment Model* (DAM) is responsible for assessing the effects of each driver of attitude change, and giving related inputs to GRAM. DAM primarily consists of a large collection of rule sets; each rule set is devoted to one particular kind of driver, e.g., civilian casualties or presence of a force group. The DAM rule sets are described in the *Athena Rules* document; see section 1.2 . A wide variety of drivers already exist in the Ground model: activity situations, environmental situations, and civilian and organization casualties; in addition, the user may created their own *Magic Attitude Drivers* (MADs), in effect writing DAM rules on the fly.

2.4 Simulated Time

Athena uses the following measures of simulated time.

Athena's clock measures time in integer *ticks* since time 0. The tick is the smallest time interval with which Athena is concerned; simulation time always advances tick-by-tick. The size of a single tick is set at initialization; it defaults to a single day of simulated time.[1]

Time 0 is mapped to wall clock time by a *start date* set by the user. Athena then outputs simulated time as either some number of integer ticks or as a zulu time string based on the start date.

1 Other values are possible, but many of Athena's models presume that the tick is no smaller than one day.

Athena is a time-step simulation; many computations take place at each time tick. Some models are triggered every so many ticks; this is called a *tock*. For example, attrition is assessed every seven ticks (by default); thus, we say that the attrition tock is seven ticks.

We expect the analyst to run Athena forward in increments of 30 to 90 days (ticks), pausing at the end of each interval to check the status and make changes. These increments are sometimes referred to as *major time steps*, or just *time steps*.[2]

At each tick, Athena performs the following steps:

- Updates the simulation time by one tick.
- Executes any scheduled events:
  - Spawning or resolving of environment situations
  - Scheduled orders
- Does a force analysis of each neighborhood, and updates the list of activity situations.
- Assesses the attitude effects of activity and environmental situations.
- At the attrition tock, assesses attrition; assesses the affect of any resulting civilian or organization casualties.
- Advances GRAM by one tick.

2 We need a better name for them, however.

3. FORCE ANALYSIS

Athena analyzes the forces present in each neighborhood and the neighborhood demographics, to determine the following quantities for each group and neighborhood:

Security: A group level of security in a neighborhood, measured as a score from -100 (very dangerous) to +100 (very safe). A group's security determines the kinds of activities the group can safely conduct within the neighborhood.

Volatility: The volatility of a neighborhood is the likelihood of spontaneous violence within the neighborhood, measured as a score from 0 (least volatile) to 100 (most volatile).

Force: A group's force in a neighborhood is its physical ability to use its assets to control that neighborhood through force. The major component of force is military strength.

3.1 Measuring Force

In general:

- The primary component of group *g*'s force in neighborhood *n* is group *g*'s assets in the neighborhood. In Athena, a group's assets are its people, whether represented explicitly in units or implicitly as the population of a neighborhood. Athena has no notion of equipment.
- Friendly military units in neighborhood *n*, i.e., those with a positive relationship with *g*, should increase *g*'s force in proportion to their numbers.
- Friendly civilians (both units and neighborhood population) in *n* should also increase *g*'s force, but by a smaller amount per person than soldiers or militia. However, an aggressive demeanor and a negative mood (S_{ng}) can increase a civilian group's force multiplier.
- Friendly contractor units in *n* may also increase *g*'s force, but personnel from friendly IGOs and NGOs are expected to remain neutral in case of conflict and do not contribute to *g*'s force.
- Friendly military units and civilians in nearby neighborhoods should also increase *g*'s force, but to a smaller extent than military units and civilians in neighborhood *n*.

- Also of interest is the force aligned against group *g*, from the groups that oppose group *g*. And just as *g* can call in its friends from nearby neighborhoods, so can *g*'s enemies.

Using these concepts we will build up a notion of force which can be used to define neighborhood volatility, and then a group's security within the neighborhood.

First, group *g*'s own force in neighborhood *n* is

$$Q_{ng} = F_{ng} \times population_{ng} + \sum_{\text{Unit } i \text{ of } g \text{ in } n} F_i \times personnel_i$$

Force of Neighborhood Population: The first term of Q_{ng} applies only for civilian groups, and is the force represented by the total population of the group in the neighborhood, whether that population is explicit (i.e., in units) or implicit. In this term, $population_{ng}$ is the total population of civilian group *g* in neighborhood *n*, and F_{ng} is a force multiplier defined as follows:

$$F_{ng} = a \times D_{ng} \times M_{ng}$$

Here, *a* is a multiplier, nominally 0.1, which reflects that only a small fraction of the population will be available to participate in a fracas at any given time.[3] D_{ng} is a multiplier based on the demeanor of *g* in *n*.[4] M_{ng} is a multiplier based on the mood S_{ng} of group *g* in *n*. It is assumed that the more aggressive the demeanor and the worse the mood, the more likely it is that civilians will use force to aid their friends and hinder their foes:

$$D_{ng} = \begin{cases} 1.5 & \text{if demeanor is Aggressive} \\ 1.0 & \text{if demeanor is Average} \\ 1.3 & \text{if demeanor is Apathetic} \end{cases}$$

$$M_{ng} = \left(1 - b \cdot \frac{S_{ng}}{100}\right)$$

Here, *b* is a factor that determines how strongly a group's mood contributes to its force.[5] If *b* is 0.2, for example, the effect of mood will range from 0.8 (when group *g* is perfectly satisfied) to 1.2 (when group *g* is perfectly dissatisfied).

3 Model parameter: `force.population`
4 Model parameter: `force.demeanor.*`
5 Model parameter: `force.mood`

Unit Force: The second term of Q_{ng} is the force of the units belonging to force or organization group *g* in neighborhood *n*, where $personnel_i$ is the number of personnel in unit *i*, and F_i is a force multiplier for unit *i*. F_i is intended to account for the effectiveness and demeanor of the unit's personnel:

$$F_i = E_i \times D_{ng}$$

D_{ng} is defined above; note that demeanor is constant across neighborhoods for force and organization groups. E_i, the unit force multiplier, should ideally depend on the type of the unit and the nature of its assets. In Athena, however, all units are the same and have no assets other than personnel, and so E_i will be determined more simply, as shown in the following table:[6]

Characteristics of Unit *i*			E_i
Unit's group type is Organization (ORG)	Group's ORG type is:	NGO	0
		IGO	0
		Contractor	2
Unit's group type is Force (FRC)	Group's force type is:	REGULAR	25
		PARAMILITARY	15
		POLICE	10
		IRREGULAR	20
		CRIMINAL	8

Effect of unit activities: At the January 2007 meeting of the JNEM Rules Committee, it was suggested that a unit's activity could affect its force multiplier. This is an intuitively attractive notion, it may contain an implicit circularity. Our model presumes that a unit can successfully perform an activity given sufficient security. If the unit's extra contribution to force due its activity depends on its ability to successfully perform the activity, then we need to have computed security to determine the unit's contribution to force...yet we need the unit's contribution to force in order to compute security.[7]

6 Model parameters: `force.orgtype.*`, `force.forcetype.*`

7 RGC: The egg had to come before the chicken. That is, whether the unit has enough security to conduct an activity has to be based on the security before it started doing the activity or it could not have started. However, rather than introduce a new time lag (which we could do), I recommend we merely look at the previous value. With this rationalization, it is no longer circular, but inevitably sequential. It would become circular if the activity lowered the unit’s effectiveness. I claim that should be taken into account when establishing the security threshold for that activity.

Effect of Group Relationships: Friends and enemies are determined by their Group Relationship, R_{nfg}, where friends have a positive relationship and enemies have a negative relationship. We assume that group *f* will assist or oppose group *g* according to the strength of the relationship from *f*'s point of view. For convenience we define

$$R^{+}_{nfg} = \begin{cases} R_{nfg} & \text{where } R_{nfg} > 0 \\ 0 & \text{otherwise} \end{cases}$$

$$R^{-}_{nfg} = \begin{cases} |R_{nfg}| & \text{where } R_{nfg} < 0 \\ 0 & \text{otherwise} \end{cases}$$

Then,

$$LocalFriends_{ng} = \sum_{f} Q_{nf} \cdot R^{+}_{nfg}$$

$$LocalEnemies_{ng} = \sum_{f} Q_{nf} \cdot R^{-}_{nfg}$$

Note that R_{nfg} need not be symmetric; if we were to replace R_{nfg} with R_{ngf} in $LocalFriends_{ng}$, then we'd be assuming that group *f* would assist group *g* based on the strength of *g*'s feeling for *f*, which might not be at all the same thing as *f*'s feeling for *g*.

Next, we take neighborhoods into account:

$$Force_{ng} = LocalFriends_{ng} + h \cdot \sum_{m \text{ near } n} LocalFriends_{mg}$$

$$Enemy_{ng} = LocalEnemies_{ng} + h \cdot \sum_{m \text{ near } n} LocalEnemies_{mg}$$

Here, *h* is a factor, nominally 0.3, that reduces the effect of friends and enemies in nearby neighborhoods.[8] The phrase "*m* near *n*" denotes those neighborhoods *m* whose $Proximity_{mn}$ is *near*, that is, those neighborhoods *m* whose inhabitants regard neighborhood *n* as being nearby. As with R_{nfg}, $Proximity_{mn}$ need not be symmetric.

In order to create scores, we'll need to normalize these values by the total force in the neighborhood:

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8 Model parameter: `force.proximity`. An appropriate value of *h* should be selected during exercise construction to reflect the criteria used for selection of neighborhood boundaries. Normally, a playbox with large neighborhoods would have a smaller value for *h* than one with small neighborhoods.

$$TotalForce_n = \sum_g Q_{ng} + h \cdot \sum_{m \text{ near } n} \sum_g Q_{mg}$$

Then,

$$\% Force_{ng} = \frac{Force_{ng}}{TotalForce_n} \times 100$$

$$\% Enemy_{ng} = \frac{Enemy_{ng}}{TotalForce_n} \times 100$$

3.2 Volatility

The volatility of a neighborhood is the likelihood of spontaneous violence within the neighborhood. Volatility depends on the balance of forces in the neighborhood, and is a key component of security. For example, an ORG group may hesitate to go into a neighborhood with high volatility, even if the ORG group is on friendly terms with all of the parties present in the neighborhood, simply because the chance of getting caught in a cross-fire is so high.

The volatility of neighborhood *n* can be regarded as a measure of the number of individuals potentially in conflict in neighborhood *n*, using the force values defined above:

$$Conflicts_n = \sum_g Enemy_{ng} \times Force_{ng}$$

$Conflicts_n$ ranges from 0 to $TotalForce_n$ because it counts every conflict from the point of view of each of the parties involved. Scaling to the range 0 to 100 yields

$$Volatility_n = \frac{Conflicts_n}{TotalForce_n^2} \times 100$$

3.3 Security

A group's security in a neighborhood determines the kinds of activities the group can perform within that neighborhood. Different levels of security are needed for different kinds of operations. The group's level of security depends on the assets present in the neighborhood, including both those belonging to the group and those belonging to friendly and unfriendly groups, as well as on the nature of both assets and groups and the general volatility of the neighborhood. In general:

- The presence of friendly forces should increase group *g*'s security within neighborhood *n*.
- The presence of enemy forces should decrease group *g's* security within neighborhood *n*.
- Increased volatility should decrease group *g*'s security within neighborhood *n*.

The security of group *g* in neighborhood *n* is defined as follows:

$$Security_{ng} = \frac{\%Force_{ng} - \%Enemy_{ng} - v \cdot Volatility_n}{100 + v \cdot Volatility_n} \times 100$$

where *v* is the volatility scaling factor, nominal 1.0, which can be used to reduce the effects of volatility on security.[9] The denominator scales $Security_{ng}$ so that ranges from -100 to +100.

For use in rules, Security_ng will usually be translated to a symbolic value, as shown in the following table:

Range	Symbol
$25 < Security_{ng} \leq 100$	High
$5 < Security_{ng} \leq 25$	Medium
$-25 < Security_{ng} \leq 5$	Low
$Security_{ng} \leq -25$	None

9 Model parameter: `force.volatility`

4. UNIT ACTIVITIES

4.1 Force Presence and Activities

Force units present in a neighborhood can affect civilian attitudes in a neighborhood in two ways: by their mere presence, and by engaging in other activities.

Force Presence: A force group's presence in a neighborhood is measured as the total number of personnel in units that belong to the group and are present in the neighborhood.[10]

Force Activities: Other activities can be assigned to any unit at any time; a unit so assigned is assumed to carry out the assigned activity if it can possibly do so. Each activity requires that the acting group have a minimum level of security in the neighborhood. The following table lists the force activities, and the nominal minimum security level for each.[11]

Force Activity	Minimum Security Required	Shifts	Coverage Function
Presence	n/a	1	25/1000
Checkpoint	Low	1	25/1000
CMO -- Construction	High	1	20/1000
CMO -- Development (Light)	Medium	1	25/1000
CMO -- Education	High	1	20/1000
CMO -- Healthcare	High	1	20/1000
CMO -- Industry	High	1	20/1000
CMO -- Infrastructure	High	1	20/1000
CMO -- Law Enforcement	Medium	1	25/1000
CMO -- Other	High	1	20/1000
Coercion	Medium	1	12/1000

10 Ideally, the nature of each unit would also be taken into account, at least at the level of "boots, wheels, or tracks," i.e., the number of personnel on foot, in wheeled vehicles, and in tracked vehicles. Tanks tear up the pavement, for example, and thus should have an increased negative effect on QOL. At present, Athena does not model units to this level of detail.

11 Model parameter database, `activity.FRC.*`

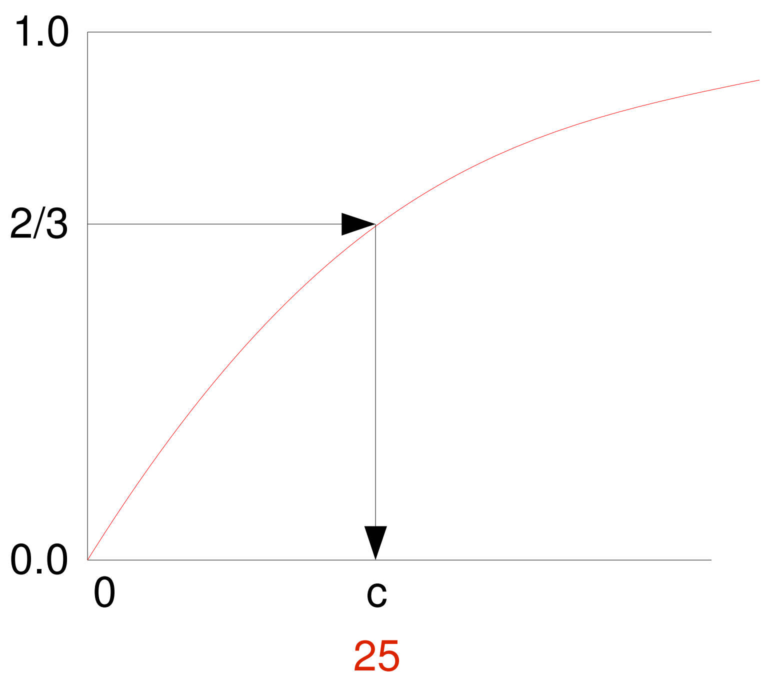
Force Activity	Minimum Security Required	Shifts	Coverage Function
Criminal Activities	Medium	1	10/1000
Curfew	Medium	1	25/1000
Guard	Low	1	25/1000
Patrol	Low	1	25/1000
PSYOP	Medium	1	1/50000

Thus, a force group can enforce a curfew or provide law enforcement in a neighborhood only if the group's security is at least Medium in that neighborhood. The extent to which a group is engaging in an activity in a neighborhood is measured by the total number of personnel in units that:

- Belong to the group
- Are present in the neighborhood
- Are assigned to do the activity
- Are on the current shift (the number of personnel available at any given time is the total divided by the number of shifts defined for the activity type)

This figure is automatically 0 if the minimum security requirement is not met.

Coverage Fractions: Whenever a group is present or conducting an activity in a neighborhood, the extent to which its presence or activities affect the local population is termed its *coverage fraction* for the activity. The coverage fraction is a value from 0 to 1; it is computed by comparing the group's personnel (present, or conducting an activity) with the total population of the neighborhood, using a function like that shown below.



In this example, if the group has deployed 25 troops per 1000 people in the neighborhood then the coverage fraction is 2/3, rising exponentially toward 1.0 as the troop density goes toward infinity. The coverage fraction determines how much of the potential satisfaction change is gained or lost by the group's presence or activity. The x-axis is usually troops per 1000 population, as shown, but can vary; for PSYOP, it is troops per 50,000 population. Thus, the two parameters required to compute a coverage fraction are $\{c, d\}$ where c is the troop density at the 2/3rds point, d is the population denominator, e.g., 1000 or 50,000. The coverage function is often specified in the form c/d. In the example shown above, then, the coverage function may be specified as either 25/1000 or {25, 1000}. The actual function is as follows. First, the troop density is

$$TD = \frac{p \cdot d}{Population_n}$$

where p is the number of personnel engaged in the activity. Then the coverage fraction is

$$CF = 1 - e^{-\frac{TD \cdot \ln 3}{c}}$$

Example: Force group g has 750 troops in neighborhood n, which has a total population of 40,000 people:

$p = 750$

$Population_n = 40{,}000$

The coverage fraction parameter, *c/d*, is nominally 25/1000 for mere presence. The troop density for group *g* is therefore

$$TD = \frac{p \cdot d}{Population_n} = \frac{750 \cdot 1{,}000}{40{,}000} = 18.75$$

The coverage fraction is therefore

$$CF = 1 - e^{-\frac{18.75 \cdot \ln 3}{c}} = 1 - e^{-0.824} = 1 - 0.44 = 0.56$$

Details of the various presence and activity rule sets are contained in the *Athena Rules* document; see section 1.2 .

A force group *g*'s coverage fraction for activity *a* in neighborhood *n* is denoted $Coverage_{nga}$.

Composite Coverage Fractions: If two force groups were cooperating in enforcing a curfew, we would expect the curfew to suppress civilian activities based on the total personnel used in enforcing it, independent of the fact that two groups are involved. In cases like these it is useful to employ a *composite coverage fraction*. This fraction can be computed based on the total troop density across all relevant groups; it can also be computed from each group's coverage fraction for the activity, as follows:

$$Coverage_{na} = 1 - \prod_g (1 - Coverage_{nga})$$

4.2 Organization Activities

Units belonging to organization groups have no effect on civilian satisfaction due to their mere presence. Organization units may perform the following activities; the effect of these activities is modeled in the same way as force activities are (section 4.1), with these distinctions. First, the minimum security required for an activity depends primarily on the organization type, and not on the activity. NGOs and IGOs require “high” security, while CTRs require “medium” security.[12] Second, organization units can perform only a subset of the activities that a force unit can perform.

12 Model parameter: `activity.ORG.*`

Organization Activity	Minimum Security Required	Shifts	Coverage Function
CMO -- Construction	High/Medium	1	20/1000
CMO -- Education	High/Medium	1	20/1000
CMO -- Healthcare	High/Medium	1	20/1000
CMO -- Industry	High/Medium	1	20/1000
CMO -- Infrastructure	High/Medium	1	20/1000
CMO -- Other	High/Medium	1	20/1000

4.3 Civilian Activities

Civilian units may perform the following activities; the effect of these activities is modeled in the same way as force activities are (section 4.1), with the distinction that (for the currently defined activities) security is irrelevant.

Civilian Activity	Minimum Security Required	Shifts	Coverage Function
Displaced Persons	n/a	1	25/1000
In Camp	n/a	1	n/a

Units assigned the "Displaced Persons" activity are assumed to contain population driven from their homes and living with and among the civilian population in the area in which they find themselves. A coverage is computed for these persons in the normal way.

Units assigned the "In Camp" activity are assumed to be displaced persons who have been settled in a refugee camp. Such persons are ignored, for two reasons. First, such camps are often established in out of the way places, where there are no local civilians to be affected. Second, the attitudes of the displaced persons themselves are of interest; but GRAM does not yet allow populations to move around in this way.

4.4 Activity Situations

When a group has an activity with coverage greater than 1.0 in a neighborhood, we way that an *activity situation* exists in that neighborhood. The effects of these situations on local attitudes are assessed by the DAM rules; see section 2.3.3 .

5. ENVIRONMENTAL SITUATIONS

Environmental situations are on-going circumstances in a neighborhood that affect all of the civilians resident in the neighborhood. Environmental situations have a coverage fraction, just as activity situations do; however, for environmental situations the coverage fraction is set by the analyst when the situation is created. The complete set of environmental situation types (and the accompanying DAM rules) are given in the *Athena Rules* document; see section 1.2 .

6. ATHENA ATTRITION MODEL (AAM)

The Athena Attrition Model (AAM, pronounced “aim”) models attrition to units and implicit civilians. In Spiral One, AAM provides a basic framework for attrition and attrition-related modeling that includes most areas, but models each area in a simple way that can be improved in later years.

Unlike traditional, detailed attrition models, which model individual firefights between opposing, detected, uniformed forces at specific points of time at specific locations, AAM models attrition caused by both uniformed and non-uniformed forces over longer periods of time (typically a week) at unspecified—but nearby—locations.

By uniformed forces we are referring to military, paramilitary or other forces wearing uniforms or other outward indication that they belong to a particular force group. By non-uniformed forces we are referring to combatants (typically insurgents) who belong to a particular force group, but who are dressed to blend in with the local civilian population in order to not be recognized by enemy forces.

AAM does not explicitly consider the effects of equipment and weapons systems in use by force units (nor are these modeled in Athena). Rather, it is assumed that forces are appropriately equipped for their activities. The effects of equipment and weapons systems are implicit in the parameters of the various equations and algorithms.

6.1 Overview

6.1.1 Attrition in the Real World

Attrition is the death of unit personnel and members of the civilian population due to inter-group violence, ranging from chance altercations to targeted attacks (assassinations and ambushes) to riots to open force-on-force combat.

In the real world, attrition can be caused by uniformed forces, non-uniformed forces, certain types of organizations (ORGs), hostile/militant civilians who do not belong to any force group, and complex crowds containing various mixes of people: non-uniformed forces, civilian supporters of force groups, "rent-a-crowds," and ordinary folks who are sympathetic to the cause, just looking for some excitement, or just happen to get caught up in things. Attrition can be suffered by all of the above, as well as by peaceful organizations and by innocent civilian bystanders.

We will not attempt to deal with all of these possibilities in Spiral One.

6.1.2 Requirements for Spiral 1

- Attrition shall take place in neighborhoods, based on the groups present in the neighborhood.
- Force groups are present in neighborhoods as unit personnel, i.e., as visible unit icons.
- Force groups may be designated as *uniformed* or *non-uniformed*.
- Organization groups are also present in neighborhoods as unit personnel, i.e., as visible unit icons.
- Civilian groups are present in neighborhoods as implicit civilian population, or as explicit personnel in visible unit icons. Civilian unit icons represent transient (e.g., refugee) population; civilian personnel in units are identical to implicit population.
- Crowds of civilians (simple or complex) will not be represented.[13]
- For convenience,
    - A Uniformed Force (UF) is the collection of all units within a neighborhood that belong to a particular force group that is designated as uniformed.
    - A Non-uniformed Force (NF) is the collection of all units within a neighborhood that belong to a particular force group it is designated as non-uniformed.
    - A Civilian "Force" (C) is a population of implicit or explicit civilians belonging to some civilian group in the neighborhood.
    - An Organization "Force" (O) is the collection of all units within a neighborhood that belong to a particular organization group.
- A neighborhood may contain any combination of UFs, NFs, Cs, and Os.
- Groups may be friendly, enemy, or neutral with each other, based on the value of their relationships.

13 At Athena's timescale, most crowd-related phenomena are events rather than situations.

- Attrition occurs during engagements between enemy forces.
- AAM shall model attrition caused by the following types of engagement:
    - UF vs. NF
        - UF hunting down enemy NF.
        - NF ambushing enemy UF.
    - Collateral damage to C from all engagements between forces.
- All casualties from attrition will be kills; there will be no computation of wounded.
- All attrition to O will be handled by magic input.
- All mass killings of C by any group will be handled by magic input.
- Coercion of civilians by force groups will be modeled as a force activity, as in JNEM; it improves cooperation if the coercing force has sufficient security and coverage. Explicit killing of C by UF or NF for the purposes of coercion will not be modeled in Spiral One.[14]
    - Putting more troops into a neighborhood allows greater opportunity for coercion.
- A UF can hunt down enemy NF in a neighborhood. In this case, the UF will benefit if it can increase the cooperation of the population with itself and decrease the cooperation of the population with the NF, as follows:
    - Fewer attacks on UF by NF
    - Better loss exchange rates for UF when NF does attack
    - More attacks by UF against NF with less collateral damage to C on each attack.
- To find enemy NF, a UF must have troops present in the neighborhood. Increasing the coverage

14 In future spirals we will add:
- Levels of coercion (mere threatening vs. actual killing)
- Tipping points (NPS coercion model)
- Time to become effective
- Levels of effectiveness based on presence of other forces and their activities
- Explicit attrition to civilians for purposes of coercion

of the troops will produce more attacks on enemy NF but will also make the UF more vulnerable to attack by NF (up to a point).

6.1.3 Requirements for Later Spirals

- To find enemy NF, a UF must have troops in the neighborhood with activities that expose them to the local population. Increasing the coverage of such activities will produce more attacks on enemy NF but will also make the UF more vulnerable to attack by NF (up to a point).
- NF requires funding/resources in order to conduct attacks against UF.
    - Reducing NF funding/resources shall reduce the number of attacks that NF can initiate against UF.
- NF can conduct IED attacks against UF.
- Force groups shall be allowed to recruit new members from the militant pools of local civilian groups.
- Individual units shall be designated as Uniformed or Non-uniformed, allowing a single force group to have both UF and NF.
- AAM shall model attrition caused by the following types of engagement.
    - C vs. C
    - UF vs. UF
    - NF vs. NF
    - Collateral damage to O from all engagements between forces.

6.1.4 Simplifying Assumptions

In order to keep AAM within the realm of the possible in Spiral One we will make the following simplifying assumptions:

- NFs will ambush UFs to inflict a few casualties and then run in order to limit their own casualties

- When a UF discovers an NF cell, the UF will attack with overwhelming force and suffer no casualties
- Neither UFs nor NFs will intentionally kill civilians in this model.[15]
- NFs will not explicitly use crowds to promote unrest or otherwise further their agenda in Spiral One.
- UFs will cause collateral damage (the killing of civilian bystanders) when attacking or defending against NFs. NFs will not kill civilians when they attack or are attacked by UF.
- There is no direct UF vs. UF or NF vs. NF conflict within the playbox.

6.2 Uniformed vs. Non-Uniformed Forces

Every force group will have a flag indicating whether it is uniformed or non-uniformed. We expect that regular military, paramilitary, and police groups will usually be uniformed (UF), and irregular military and criminal groups will usually be non-uniformed (NF).

6.3 Units and Unit Activities

Rather than representing a specific body of troops in some location, an Athena unit really represents an allocation of some number of personnel to an activity within the neighborhood, such as PATROL or COERCION. Troops assigned the activity NONE are presumed to be in reserve. At Athena's time scale, it makes no sense to model unit movement or location in any detail. Athena units have a precise location within each neighborhood, but only as an aid to visualization.

Some activities involve more exposure to the local population than others. Increased exposure has a number of effects: the unit is more likely to find enemy units; the unit is more likely to get intel from the local civilians; the unit is more likely to be attacked by enemy units. The following force activities are deemed to involve significant exposure to the local civilians:

CHECKPOINT
CMO_CONSTRUCTION
CMO_DEVELOPMENT

15 Mass killings can be handled via magic input. Killing as a coercion technique will not be explicit in Spiral One.

CMO_EDUCATION
CMO_EMPLOYMENT
CMO_HEALTHCARE
CMO_INDUSTRY
CMO_INFRASTRUCTURE
CMO_LAW_ENFORCEMENT
CMO_OTHER
COERCION
CRIMINAL_ACTIVITIES
CURFEW
PATROL
PSYOP

However, the results of such increased exposure are being deferred to a later spiral.

The following activities do not have significant exposure in the sense used here:

GUARD
NONE

6.4 Unit Number and Unit Size

Because units are used to allocate troops to particular activities, rather than to represent any military TOE, the breakdown of a force into units has no tactical significance. (Barring the convenience of the analyst, there is no reason to have two units in a neighborhood with the same group and activity.) Consequently, the breakdown of a force into units will be ignored when computing attrition.

6.5 Magic Attrition

The analyst can attrit units and groups magically:

6.5.1 Magic Attrition to Units

The analyst can attrit a specific unit, of any type. The attrition comes out of the unit's personnel. If it is a civilian or organization unit, the attrition will be assessed by the relevant DAM rule set.

6.5.2 Magic Attrition to Groups

The analyst can attrit a specific group in a specific neighborhood. The analyst can also choose to attrit all civilians in a neighborhood. The attrition is applied as described in Section 6.9 , and civilian and organization attrition will be assessed by the relevant DAM rule set.

6.6 Antagonists and ROEs

Neighborhood *n* can contain the kinds of forces listed in Section 6.1.2 : NF, UF, and C.[16] Attrition occurs when two forces *a* and *b* are antagonists as defined in this section.

6.6.1 Civilian Antagonists

This model is deferred until after Spiral One.

A civilian "force" is simply a neighborhood group. Two neighborhood groups are antagonistic if at least one regards the other as an ENEMY. We can compute the degree of antagonism between groups *nf* and *ng* as follows:

$$antagonism_{nfg} = \min(R_{nfg}, R_{ngf})$$

If $antagonism_{nfg}$ falls in the ENEMY range, then groups *nf* and *ng* are antagonists, and will cause attrition to each other.

6.6.2 Attacking ROEs: UF

In Spiral One, uniformed forces (UF) may attack non-uniformed forces (NF) in a neighborhood.

A UF will attack a particular NF only when directed to do so by its Rules of Engagement. In principle, each UF has an *attacking ROE* with respect to each NF This ROE may be set to

- ATTACK
- DO_NOT_ATTACK

16 We are ignoring organization group "forces" in Spiral One.

An ATTACK ROE is further qualified by a Cooperation limit: the UF will attack only if its composite cooperation with the residents of the neighborhood exceeds some value.

In practice, Athena will only track ROEs set to ATTACK; if no ROE is set, no attacks will take place.

For example, consider the following Attacking ROE table, in which BLUE is a uniformed force and ALQ is a non-uniformed force.

Nbhood	***f***	***g***	**Coop. Limit**
N1	BLUE	ALQ	25
N2	BLUE	ALQ	40

This table indicates that Blue has been ordered to attack Al Qaeda in neighborhood N1 provided that cooperation of the residents of N1 with Blue is at least 25%, and in neighborhood N2 provided that cooperation is at least 40%. However, Blue will not attack Al Qaeda in any other neighborhood.

6.6.3 Attacking ROEs: NF

In Spiral One, non-uniformed forces (NF) may attack uniformed forces (UF) in a neighborhood.

Just as with UFs, an NF will attack a particular UF only when ordered to do so by its Rules of Engagement. In principle, each NF has an *attacking ROE* with respect to each UF. This ROE may be set to

- HIT_AND_RUN: The NF will attempt to kill UF troops through ambushes, IED attacks, and so forth, while limiting their own losses by running as soon as possible.
- STAND_AND_FIGHT: The NF will attempt to kill UF troops by sucking them into an ambushes and pinning them down, so as to kill as many UF troops as possible regardless of their own losses.
- DO_NOT_ATTACK

The HIT_AND_RUN and STAND_AND_FIGHT ROEs are further qualified by a Cooperation limit: a force will attack only if its composite cooperation with the residents of the neighborhood exceeds some value.

In addition, the HIT_AND_RUN and STAND_AND_FIGHT ROEs include a nominal number of attacks per day.[17]

In practice, Athena will not track ROEs set to DO_NOT_ATTACK; if neither HIT_AND_RUN nor STAND_AND_FIGHT is set, no attacks will take place.

For example, consider the following Attacking ROE table, in which BLUE is a uniformed force and ALQ is a non-uniformed force.

Nbhood	***f***	***g***	**ROE**	**Coop. Limit**	**Attacks/Day**
N1	ALQ	BLUE	STAND_AND_FIGHT	40	0.2
N2	ALQ	BLUE	HIT_AND_RUN	40	0.5

Al Qaeda will attack Blue in both neighborhoods, given at least 40% cooperation. In N1 it will try to attack once every five days, and will stand and fight, taking greater casualties. In N2, however, it will try to attack more often, every other day, but will try to conserve its strength by using hit and run tactics.

6.6.4 Defending ROEs

In addition to its Attacking ROEs, each uniformed force has a Defending ROE, which can have one of three values:

- FIRE_BACK_IMMEDIATELY: Fire back immediately if fired upon. This will cause collateral damage to civilians whenever the UF defends itself.
- FIRE_BACK_IF_PRESSED: Do not fire back unless the enemy continues to engage. This will cause collateral damage to civilians only when the UF defends itself against an NF with an attacking ROE of STAND_AND_FIGHT.
- HOLD_FIRE: Do not fire back. The UF will never cause collateral damage when defending.

In Spiral One this ROE affects only the response of a UF when attacked by an NF. It is defined for every UF in every neighborhood, and defaults to FIRE_BACK_IF_PRESSED.

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17 In Spiral 2, this number will be computed automatically from the resources available to the NF.

6.7 The Attrition Cycle

Attrition will be computed at regular intervals; the default interval is one week, i.e., 7 ticks,[18] which is comfortably smaller than the required Athena game turn of 1 to 3 months. Thus, attrition that occurs during the game turn can have an impact during that game turn.

At the end of the attrition interval, the following algorithm will compute the attrition for the interval:

For each neighborhood *n,*
  Determine each pair *a,b* of antagonists in *n*.
  For each pair *a,b*
    Compute attrition for each pair, according to the kind of antagonists.
      UF vs. NF
      NF vs. UF
    Accumulate the attrition to each force.
  Apply all attrition at the end.

Note that the outcome is independent of the order in which the pairs are processed, as the attrition is applied to each force after all attrition has been computed. This is standard for Lanchester attrition models: all the bullets are fired, and then they all hit at once.

6.8 Computing Attrition

6.8.1 Uniformed vs. Non-uniformed

Non-uniformed forces operate in small cells and hide among the civilian population. ROE permitting, a UF will attack an NF cell every time it gets a chance, and will do so with overwhelming force. Every cell found will be destroyed, and collateral damage to civilians is likely. There will be no UF casualties in Spiral One as a result of UF attacks on NF cells.

The UF must find the NF cells in order to attack them. The number of cells found increases with:

- The number of troops in the UF: the more troops, the more chance of contact.
- Increased cooperation of the civilians with the UF, because the UF will get more intel.

18 Model parameter: `aam.ticksPerTock`

- Decreased cooperation of the civilians with the NF, because the civilians are less likely to warn the NF of an impending attack.

- The number of troops in the NF: the more troops, the easier they are to find.

- **Spiral Two or** later: The exposure of the UF troops to the population (i.e., the UF units are assigned activities that imply contact with the locals); you can't find the bad guys while guarding the base.

Let

ΔT	=	The duration of the attrition interval in days
Ω_{NF}	=	The composite cooperation of the civilians in *n* with the NF.
Ω_{UF}	=	The composite cooperation of the civilians in *n* with the UF.
N_p	=	The possible number of attacks by the UF on the NF during the interval.
N_a	=	The actual number of attacks by the UF on the NF during the interval
cov_{UF}	=	The actual coverage fraction of the UF .[19]
$nomcov_{UF}$	=	The nominal coverage fraction of the UF for this algorithm.[20]
cov_{NF}	=	The coverage fraction of the NF.[21]
$nomcov_{NF}$	=	The nominal coverage fraction of the NF for this algorithm.[22]
TF	=	The average time to find an NF cell, given equal cooperation and the nominal coverage fractions.[23] This is the parameter that drives this part of the model.

Then, we compute the possible number of attacks as follows:

$$N_p = \text{round}\left(\frac{\Omega_{UF}}{\max(\Omega_{NF}, 10.0)} \times \frac{cov_{UF}}{nomcov_{UF}} \times \frac{cov_{NF}}{nomcov_{NF}} \times \frac{\Delta T}{TF}\right)$$

19 Computed in-line using a coverage function; model parameter: `aam.UFvNF.UF.coverageFunction`

20 Model parameter: `aam.UFvNF.UF.nominalCoverage` e.g., 0.3 (depends on what would be expected as average in this scenario)

21 Computed in-line using a coverage function; model parameter: `aam.UFvNF.NF.coverageFunction`. This is identical to the default COERCION coverage function.

22 Model parameter: `aam.UFvNF.NF.nominalCoverage`, e.g., 0.4

23 Model parameter: `aam.UFvNF.UF.timeToFind`, e.g., 5 days

Thus, when the cooperation levels are balanced ($\Omega_{NF} = \Omega_{UF}$), and when the coverage fractions are at their nominal levels, we get precisely the average number of attacks during the interval

$$N_p = \text{round}\left(\frac{\Delta T}{TF}\right)$$

The possible number of attacks is increased by increased cooperation of the population with the UF, and by increased coverage for either group, and is decreased by increased cooperation of the population with the NF, as desired.

Next, we must determine the actual number of attacks, and the attrition resulting from them. Let

$cellsize$	=	The average number of troops per NF cell.[24]
$personnel_{NF}$	=	The number of NF troops in the neighborhood.

The number of cells is then

$$N_{cells} = \text{ceiling}\left(\frac{personnel_{NF}}{cellsize}\right)$$

Since each attack kills an entire cell, the actual number of attacks cannot exceed the number of cells:

$$N_a = \min(N_p, N_{cells})$$

The number of NF troops killed is then

$$N_{killed} = \min(N_a \times cellsize, personnel_{NF})$$

Next, we must compute civilian casualties. Let

$\hat{\Omega}_{UF}$	=	The nominal composite cooperation of the neighborhood with the UF for this algorithm.[25]
$ECDA$	=	The Expected Collateral Damage per Attack, i.e., the number of civilians killed for each attach on an NF cell, assuming nominal cooperation. This value will depend on the urbanization level of the neighborhood (rural, suburban, urban).

24 Initially, this will be a model parameter, `aam.UFvNF.NF.cellSize`, e.g., 7 NF/cell in every neighborhood. Later, it might be allowed to vary by group and by neighborhood.

25 Model parameter: `aam.UFvsNF.UF.nominalCooperation`, e.g., 35 %

For example, if *ECDA* is 2.0, then we expect two civilian casualties for each cell killed.[26]

Then

$$N_{civcas} = \text{floor}\left(N_a \times ECDA \times \frac{\hat{\Omega}_{UF}}{\max(\Omega_{UF}, 10.0)} \right)$$

If the actual cooperation of the neighborhood with the UF is exactly the nominal, then the civilian casualties will be just as expected. If the nominal cooperation is 50%, then better than nominal cooperation can cut casualties in half—but minimal cooperation (10% or less) can increase casualties by a factor of five.

6.8.2 Non-uniformed vs. Uniformed

An NF will attack a UF every time it can (given the ROE to attack). Obviously, the NF can only attack if both the NF and the UF have personnel in the neighborhood. However, the number of such attacks is limited by the NF's resources[27], the availability of UF target opportunities, the cooperation of the civilian population with the NF, and the desire of the NF to limit their casualties as indicated by their ROE (HIT_AND_RUN or STAND_AND_FIGHT). In particular, the number of potential attacks should:

- Vary inversely with UF security
- Vary directly with the cooperation of the neighborhood with the NF.
- Vary directly with the coverage of UF units in the neighborhood.

First we compute N_p, the number of potential attacks:

$$N_p = \text{round}\left(\frac{100 - security_{UF}}{100} \times \frac{\Omega_{NF}}{\hat{\Omega}_{NF}} \times \frac{cov_{UF}}{nomcov_{UF}} \times rate \times \Delta T \right)$$

where

26 Model parameter: `aam.UFvsNF.ECDA.`*`urbanization`*, e.g., 1 in rural, 3 in suburban, and 5 in urban.
27 In Spiral 2.

rate	=	The nominal attack rate per day.[28]
$security_{UF}$	=	The UF's security in the neighborhood. Security ranges from -100 to +100.
Ω_{NF}	=	The composite cooperation of the neighborhood with the NF.
$\hat{\Omega}_{NF}$	=	The nominal cooperation of the neighborhood with the NF for this algorithm.[29] This parameter depends on the ROE, HIT_AND_RUN or STAND_AND_FIGHT.
cov_{UF}	=	The actual coverage fraction of the UF, based on total personnel in the neighborhood.[30]
$nomcov_{UF}$	=	The nominal coverage fraction of the UF for this algorithm.[31] This parameter depends on the ROE, HIT_AND_RUN or STAND_AND_FIGHT.
ΔT	=	The duration of the attrition interval in days.

If N_p is 0, then of course the NF cannot attack. Otherwise, whether the NF will actually attack or not depends on the ROE, HIT_AND_RUN or STAND_AND_FIGHT.

6.8.2.1 Loss Exchange Ratio

The loss exchange ratio (LER) for an attack is the number of NF casualties for each UF trooper killed. If the NF killed four UF personnel at a loss of one NF personnel, that would be an LER of ¼. AAM determines the loss exchange ratio (LER) as follows:

$ELER_{ROE}$	=	The Expected Loss Exchange Ratio: the expected number of NF casualties per UF casualty, when the UF fires back. This number depends on the NF's attacking ROE.[32]
Ω_{NF}	=	The composite cooperation of the neighborhood with the NF.
Ω_{UF}=	=	The composite cooperation of the neighborhood with the UF.

28 Ideally, the number of attacks should depend on the NF's resources, so that attacking the resources will reduce the number of attacks. Our notion is that the nominal number of attacks is determined by a Z-curve whose X-axis is a measure of the resources available to the NF. The currently envisioned model is that this measure is the weighted sum of the economic clout of the actors that have influence over the NF, weighted by the relationships between the NF and the actors. All this must wait until Spiral 2, however. For, the attack rate per day is part of the NF's attacking ROE.

29 Model parameter: `aam.NFvsUF.`*`roe`*`.nominalCooperation`, e.g., 50%.

30 Model parameter: `aam.NFvsUF.UF.coverageFunction`, e.g., {25 1000}.

31 Model parameter: `aam.NFvsUF.UF.nominalCoverage`, e.g., 0.2

32 Model parameter, `aam.NFvsUF.`*`roe`*`.ELER`, e.g., 0.33 for HIT_AND_RUN, 3.0 for STAND_AND_FIGHT.

$MAXLER_{ROE}$ = The maximum loss exchange ratio the NF is willing to accept when attacking with the specified ROE.[33]

Then

$$LER_{ROE} = ELER_{ROE} \times \frac{\Omega_{UF}}{\max(\Omega_{NF}, 10)}$$

In other words, the loss exchange ratio depends on the intelligence available to the NF and to the UF, as indicated by the cooperation of the neighborhood with each. As UF's intel improves, the LER gets larger; as NF's intel improves, the LER gets smaller. If the neighborhood cooperates equally with both, it's a wash and the LER is simply the expected LER.

The NF will only attack if the LER is their favor. That is,

If $LER_{ROE} \leq MAXLER_{ROE}$
Then attack,
Otherwise do not attack.

6.8.2.2 NF and UF Casualties

Hit-and-Run: When the ROE is HIT_AND_RUN, the NF will husband their forces, trying to do damage to the UF without losing too many people. We assume that the NF wants to inflict $UFCAS_{ATTACK}$ casualties on the UF during each attack.[34] Since they would not be attacking unless the Loss Exchange Ratio were in their favor, we know that they are prepared to take $NFCAS_{ATTACK}$ casualties in each attack, where

$$NFCAS_{ATTACK} = UFCAS_{ATTACK} \times LER_{ROE}$$

Stand-and-Fight: When the ROE is STAND_AND_FIGHT, on the other hand, the NF is prepared to suffer significant casualties in order kill UF personnel. We assume that the NF is willing to expend $NFCAS_{ATTACK}$ personnel to kill as many UF personnel as they can.[35] Given the LER, they can then kill

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33 Model parameter, `aam.NFvsUF.`*`roe`*`.MAXLER`, e.g., 0.25 for HIT_AND_RUN, 4.0 for STAND_AND_FIGHT.

34 Model parameter, `aam.NFvsUF.HIT_AND_RUN.ufCasualties,` e.g., 4.

35 Model parameter, `aam.NFvsUF.STAND_AND_FIGHT.nfCasualties`, e.g., 20

$$UFCAS_{ATTACK} = \frac{NFCAS_{ATTACK}}{\max(LER_{ROE}, 0.01)}$$

In either case, the number of NF casualties actually incurred depends on the Defending ROE of the UF: unless they fire back, no NF personnel will be killed. However, the NF must make their plans presuming that the UF will fire back.

Now, the NF can potentially make N_p attacks, given their access to the UF forces. The actual number of attacks is limited by the NF and UF personnel available. The NF cannot kill more UF personnel than are there, and will do so with the fewest casualties to themselves; and since they must presume that the UF will fire back they cannot schedule more attacks than they have personnel to lose. Thus, the actual number of attacks N_a is computed as follows.

$$N_a = \text{floor}\left[\min\left(N_p, \frac{personnel_{NF}}{NFCAS_{ATTACK}}, \frac{personnel_{UF}}{UFCAS_{ATTACK}}\right)\right]$$

Given that an attack is possible, and the LER is in the NF's favor, the NF will **always** attack at least once.

The total number of UF casualties is then

$$UFCAS_{TOTAL} = \text{floor}\left(\min\left(N_a \times UFCAS_{ATTACK}, personnel_{UF}\right)\right)$$

NF and civilian casualties depend on whether or not the UF fires back, as shown in the following table:

NF Attacks	UF Defends	UF Fires Back
HIT_AND_RUN	FIRE_BACK_IMMEDIATELY	Yes
HIT_AND_RUN	FIRE_BACK_IF_PRESSED	No
HIT_AND_RUN	HOLD_FIRE	No
STAND_AND_FIGHT	FIRE_BACK_IMMEDIATELY	Yes
STAND_AND_FIGHT	FIRE_BACK_IF_PRESSED	Yes
STAND_AND_FIGHT	HOLD_FIRE	No

If the UF fires back, then the number of NF casualties is

$$NFCAS_{TOTAL} = \text{floor}\left(\min\left(UFCAS_{TOTAL} \times LER_{ROE}, personnel_{NF}\right)\right)$$

Otherwise, no NF casualties are incurred.

6.8.2.3 Civilian Collateral Damage

For Spiral One we assume no collateral damage from the NF attack itself—NF does not want to kill civilians in these attacks, but would be glad if UF fired back and did kill some. Thus, civilian casualties occur only if the UF fires back. In this case, the total number of civilian casualties is

$$CIVCAS_{total} = ECDC \times NFCAS_{TOTAL}$$

where

ECDC	=	the Expected Collateral Damage per NF Casualty. This is a model parameter which depends on the urbanization level (urban, suburban, or rural) of the neighborhood, and on the NF's ROE.[36]

6.9 Applying Attrition

All attrition is computed before any attrition is applied to the neighborhood.

6.9.1 Force Group Attrition

As stated above, it is assumed that units with more important activities will be replenished with personnel from units with less important activities. Each activity will be assigned a priority, and NF and UF casualties will be allocated to units in this order. Activity NONE will have the lowest priority.

The priority order is as follows:

NONE
CMO_CONSTRUCTION

36 Model parameter: `aam.NFvsUF.ECDC.`*`urbanization`*, e.g., 0.1 for RURAL, 0.15 for SUBURBAN, 0.2 for URBAN

CMO_DEVELOPMENT
CMO_EDUCATION
CMO_EMPLOYMENT
CMO_INDUSTRY
CMO_INFRASTRUCTURE
CMO_LAW_ENFORCEMENT
CMO_OTHER
CMO_HEALTHCARE
CRIMINAL_ACTIVITIES
COERCION
PSYOP
CURFEW
CHECKPOINT
PATROL
GUARD

Units with zero personnel will have a gray background on the map display.

In Spiral Two, attacks on force groups should affect civilian attitudes, apart from any civilian casualties.

6.9.2 Organization Group Attrition

As with force units, it is assumed that organization units with more important activities will be replenished with personnel from units with less important activities. Each activity will be assigned a priority, and casualties will be allocated to units in this order. Activity NONE will have the lowest priority. The effect of these casualties will be assessed by the ORGCAS rule set in the Driver Assessment Model (DAM).

The priority order is as follows.

NONE
CMO_CONSTRUCTION
CMO_DEVELOPMENT
CMO_EDUCATION
CMO_EMPLOYMENT
CMO_INDUSTRY
CMO_INFRASTRUCTURE

CMO_LAW_ENFORCEMENT
CMO_OTHER
CMO_HEALTHCARE

Units with zero personnel will have a gray background on the map display.

6.9.3 Civilian Attrition

For civilian attrition, there are two distinct cases: attrition to a specific neighborhood group, and collateral damage to the neighborhood as a whole. Both are handled in essentially the same way.

First, we build a list of the bodies that can be attrited: implicit neighborhood populations, and civilian units. When we attrit a specific neighborhood group, the list of bodies includes the group's implicit population and each of the group's units that is in its home neighborhood. When we attrit all civilians in the neighborhood it includes the implicit populations of all resident groups along with all civilian units located in the neighborhood.

Next, we sort the list in decreasing order of size.

Next, we compute the fraction of the neighborhood's population represented by each of the bodies.

Next we apply attrition to each body in turn, attriting it by its proportional share of the casualties. Let

casualties	=	The total number of casualties to inflict
i	=	The index of the ith body to receive casualties
f_i	=	The fraction of *casualties* to be taken by i.

Then,

Let r := *casualties*
For each body i to be attrited,
Let $k = \min\left(r, \text{ceiling}(f_i \times casualties)\right)$
Apply k casualties to r.
Let $r = r - k$
If r is 0, then stop.

This algorithm rounds fractional casualties in favor of the smaller bodies; the smallest body will tend to get less than its "fair" share of casualties.

The effect of these casualties will be assessed by the CIVCAS rule set in the Driver Assessment Model (DAM).

6.10 Assessing the Attitude Implications

Once attrition has been computed and applied, it is necessary to assess the implications for civilian and organization attitudes via the CIVCAS and ORGCAS rule sets in the Driver Assessment Model (DAM).

6.10.1 Contrasted with JNEM

In theory, JNEM assesses civilian and organization casualties incident by incident—in theory, because it is the ground model's responsibility to decide what constitutes an incident, and some ground models do a better job than others. In consequence, JNEM accumulates all attrition to a group occurring within a short window, and calls that an "incident". From this attrition, JNEM computes the effective number of kills, and passes this through a Z-curve to get a multiplier which is used to scale the magnitudes in the CIVCAS rules.

In general, then, attrition happens when it happens, and the attitude effects of different incidents can interfere with each other (based on sharing the same cause) as they play out over time.

In Athena, we assess attrition periodically, nominally once a week, reflecting the incidents that have implicitly occurred over the previous week. So long as we approach attrition in this aggregate way, there's no way to assess it incident by incident. It is clearly wrong to say, "There were 17 fire fights this week in which Punjabis were killed in this neighborhood, so we'll have 17 inputs to GRAM all timestamped today and all with the same cause." Consequently, we will assess the attitude implications once per week as well, based on the aggregate attrition over the week.

Magic attrition to civilian and organization groups will be applied to those groups as it occurs, but the total attrition will be saved and assessed with the normal attrition at the end of the week.

6.10.2 Satisfaction Effects of Attrition

We will assess the satisfaction effects of attrition on a civilian or organization group as follows. First, all attrition occurring during the week, both magic and normal, to group *f* in neighborhood *n* will be accumulated in the **attrit_nf** table. Let

n	=	The neighborhood
f	=	The attrited civilian or organization group. If *f* is a civilian group, it must be resident in neighborhood *n*.
$ftype$	=	The group type, CIV or ORG.
$casualties$	=	The total number of casualties to *f* in *n* during the week.
$ZSAT_{ftype}()$	=	A Z-curve, dependent on the group type, which converts a total number of casualties into a casualty multiplier used in the CIVCAS or ORGCAS satisfaction rules.[37]
M	=	The casualty multiplier.

We compute the casualty multiplier, *M*, as follows:

$$M = ZSAT_{ftype}(casualties)$$

When the CIVCAS or ORGCAS rule set is triggered, it has access to *n*, *f*, *casualties*, and *M*.

6.10.3 Cooperation Effects of Attrition

Athena only tracks the cooperation of neighborhood groups with force groups; consequently, we assess cooperation effects only for attrition to civilian groups. The CIVCAS rule set attends to this.

All normal civilian attrition is (at present) due to collateral damage resulting from fighting between two force groups. Magic attrition can optionally be attributed to one or two force groups. As attrition occurs, Athena accumulates the total casualties to group *f* in neighborhood *n* in which force group *g* was in some way involved in the **attrit_nfg** table. If two force groups are involved in an altercation, as is usually the case, the total civilian casualties are attributed equally to both.

Then, let

n	=	The neighborhood

37 Model parameters: `dam.CIVCAS.Zsat, dam.ORGCAS.Zsat`

f	=	The attrited civilian group, resident in n.
g	=	A force group.
$casualties$	=	The total number of casualties to f in n during the week in which g was involved.
R_{nfg}	=	The relationship between neighborhood group nf and force group g.
$ZCOOP()$	=	A Z-curve which converts a total number of casualties into a casualty multiplier used in the CIVCAS coop rules.[38] It will usually be the same as $ZSAT_{CIV}()$
M	=	The resulting casualty multiplier.

We compute the casualty multiplier, M, as follows:

$$M = ZCOOP(casualties)$$

When the CIVCAS rule set is triggered it has access to n, f, g, $casualties$, R_{nfg}, and M. The actual magnitude of the rule firing will be

$$magnitude = M \times \text{enmore}\left(R_{nfg}\right) \times \text{M-}$$

where M- connotes a medium-sized negative (i.e., -5.0 point) effect. See the *Athena Rules* document for details on how rule magnitudes are specified.

38 Model parameter: `dam.CIVCAS.Zcoop`

7. DEMOGRAPHICS

The Athena Demographics model (DEMOG) models the number of people in the civilian population broken down in a variety of ways. In the long run, this model will handle births, deaths due to old age and other causes, and aging of the population; in Spiral One it will track only the following:

- The base population, by neighborhood group, as of time 0.
- The number of deaths due to attrition for each neighborhood group.
- The explicit population, as represented by civilian unit icons.
- Displaced population, as represented by civilian unit icons located outside their neighborhood of origin.

And, taking all of these into account,

- The total population of a neighborhood group in its own neighborhood at the current time, whether represented implicitly or in units.
- The total labor force present in a neighborhood, including both resident and displaced population present in the neighborhood.

7.1 Requirements for Spiral One

The Spiral One demographic is intended to be as simple as possible while meeting the needs of the other Athena models. In particular:

- GRAM requires the current population of each neighborhood group.
- The Ground model requires that the civilian population of a neighborhood can be displaced to other neighborhoods in the form of units.
- The Athena Attrition Model (AAM) requires that the civilian population can take collateral damage as the result of combat between forces.

Consequently,

- The playbox population is initially stated as the population of each neighborhood group.
- Civilian population can be implicit (tracked by neighborhood group) or explicit (tracked by civilian unit icons).
- Implicit population can be made explicit by moving people into units.
- Explicit population can be made implicit by moving people out of units.
- Explicit population can be *displaced*; that is, a unit belonging to a neighborhood group can be moved out of its neighborhood of origin.
  - The reason for the displacement can be indicated by by setting the unit's activity, e.g., to DISPLACED; however, this is outside the scope of DEMOG.
- Both implicit and explicit population can be attrited.

7.2 Simplifying Assumptions

In order to keep DEMOG within the realm of the possible we will make the following simplifying assumptions in Spiral One:

- Births, and deaths from causes other than attrition, will not be tracked.
- The population does not age.
- The labor force is a simple fraction of the total population, taking civilian activities (e.g., refugee status) into account.[39]

7.3 Neighborhood Group Population

The implicit population IP_{ng} of neighborhood group *ng* at the current time is

$$IP_{ng} = BP_{ng} - EP_{ng} - attrition_{ng}$$

39 The labor force will be required by the Athena Economics model, which is scheduled for Spiral 2.

where

BP_{ng}	=	The base population of group *ng* at time zero, as defined in the scenario.
EP_{ng}	=	The explicit population: the total number of personnel in units belonging to *ng*, i.e., the total number of people moved from the implicit population into units.
$attrition_{ng}$	=	The total number of casualties suffered by group *ng* to date.

Now, some of the explicit population might be displaced out of the neighborhood. The total population of group *ng* in neighborhood *n* is therefore:

$$population_{ng} = BP_{ng} - DP_{ng} - attrition_{ng}$$

where

DP_{ng}	=	The displaced population: the total number of personnel in units belonging to group *ng* but located somewhere other than in neighborhood *n*.

7.3.1 Civilian Units

When a civilian unit *u* is created, it must be created for a specific neighborhood group *ng*, and it must be created with a specific number of personnel, $personnel_u$, where $personnel_u \leq IP_{ng}$. That is, explicit population comes out of the implicit population.

Note that moving personnel from the implicit population to units and *vice versa* does not change the population of the neighborhood, unless the units are displaced.

7.3.2 Civilian Attrition

Both implicit and explicit population can be attrited. Attrition to the implicit population is handled by adding the casualties to $attrition_{ng}$:

$$attrition_{ng} = attrition_{ng} + casualties$$

Attrition to the explicit population, that is, to civilian unit personnel, is handled simply by subtracting the casualties from the unit's personnel, thus returning them to the implicit population, and then adding them to $attrition_{ng}$ as before. In either case, the number of casualties is limited to the population available.

7.4 Neighborhood Population

The total population of neighborhood *n* is simply the implicit population of all civilian groups in the neighborhood plus all personnel in civilian units in the neighborhood:

$$population_n = \sum_{g \in CIV} IP_{ng} + personnel_{ng}$$

Where

IP_{ng}	=	The implicit population, as defined above.
$personnel_{ng}$	=	The number of personnel in units belonging to group *g* currently located in neighborhood *n*, whether displaced or not.

Total population determines the consumption of economic goods; everyone needs to eat. However, only a fraction of the population can work. The labor force in *n,* LF_n, can be defined as

$$LF_n = LFF \times population_n$$

Where

LFF	=	The labor force fraction, a model parameter nominally set to 0.6.

However, this assumes that the explicit population always contributes to the labor force, which is not clear. Refugees might or might not; pilgrims (when we have pilgrims) probably do not. Clearly, civilian activity affects the contribution to the labor force. Alternatively, then, we can define the labor force as follows:

$$LF_n = \left(LFF(\text{NONE}) \times \sum_{g \in CIV} IP_{ng} \right) + \left(\sum_u LFF(a_u) \times personnel_u \right)$$

Where

$LFF(a)$	=	The labor force fraction, a model parameter that depends on the civilian activity.[40]
u	=	A civilian unit in neighborhood n.
a_u	=	The activity assigned to unit u.
$personnel_u$	=	The personnel in unit u.

40 Model parameter: `demog.laborForceFraction.*`

8. ACRONYMS

AAM	Athena Attrition Model
AUT	Autonomy (concern)
CIV	Civilian
CMO	Civil/Military Operations
CTR	Contractor
CUL	Culture (concern)
DAM	Driver Assessment Model
ECDA	Expected Collateral Damage per Attack
ECDC	Expected Collateral Damager per NF Casualty
ELER	Expected Loss Exchange Ratio
FRC	Force
GRAM	Generalized Regional Attitude Model
IED	Improvised Explosive Device
IGO	International or Inter-Governmental Organization
JNEM	Joint Non-lethal Effects Model
LER	Loss Exchange Ratio
LFF	Labor Force Fraction
MAD	Magic Attitude Driver
MAG	Mars Analyst's Guide
NF	Non-uniformed Force
NGO	Non-Governmental Organization
ORG	Organization
QOL	Quality of Life (concern)
ROE	Rules Of Engagement
S&RO	Stability & Recovery Operations
SFT	Safety (concern)
UF	Uniformed Force
UNESCO	United Nations Educational, Scientific, and Cultural Organization