**Athena User's Guide**

Athena S&RO Simulation, V3

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William H. Duquette

Jet Propulsion Laboratory

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**Table of Contents**

Part I: Overview 4

1. Introduction 5

1.1 Overview of This Document 5

1.2 Other Documents 5

1.3 Changes for Athena 3 6

2. Athena Model Overview 8

2.1 The Simulation and its Objects 8

2.2 The Six Modeling Areas 9

3. Ground 12

3.1 Simulated Time 12

3.2 The Playbox 12

3.2.1 Neighborhoods 12

3.2.2 Neighborhood Proximity 13

3.2.3 Neighborhood Effects Delay 13

3.2.4 Local vs. Non-Local Neighborhoods 13

3.2.5 Production Capacity 14

3.3 Actors 14

3.4 Groups 15

3.4.1 Civilian Groups 15

3.4.2 Force Groups 15

3.4.3 Organization Groups 16

3.5 Deployment 16

3.6 Activity Assignment 17

3.7 Units 17

3.8 Volatility and Security 17

3.9 Coverage 19

3.10 Activity Situations 19

3.11 Environmental Situations 20

3.12 Athena Attrition Model 21

3.12.1 Rules of Engagement 21

3.12.2 Presence and Intelligence 21

3.12.3 Attrition Assessment 22

3.12.4 Magic Attrition 22

3.13 Essential Non-Infrastructure (ENI) Services 22

3.13.1 The Notion of a Service 22

3.13.2 Services vs. Environmental Situations 24

3.13.3 Measurement of ENI Services 24

3.13.4 Required Level of ENI Services 24

3.13.5 Status Quo ENI Funding 24

3.13.6 Effects of ENI Services 25

4. Demographics 26

4.1 Base Population 26

4.2 Current Population 26

4.3 Subsistence Agriculture 26

4.4 Consumers and Workers 27

4.5 Demographic Situations 27

5. Attitudes 28

5.1 Belief Systems and Affinities 28

5.1.1 Beliefs and Topics 29

5.1.2 Affinity 30

5.1.3 Playbox Commonality 30

5.1.4 Entity Commonality 30

5.2 Horizontal Relationships 31

5.2.1 Relationship Overrides 31

5.3 Vertical Relationships 31

5.3.1 Force and Organization Groups 32

5.3.2 Civilian Groups 32

5.4 Satisfaction Levels 32

5.4.1 The Four Concerns 33

5.4.2 Saliencies 33

5.4.3 Group Mood 33

5.5 Cooperation Levels 34

5.6 Trends and Thresholds 34

5.7 The Driver Assessment Model (DAM) 34

5.7.1 Level and Slope Inputs 35

5.7.2 Direct and Indirect Effects 35

5.8 Magic Attitude Drivers 35

6. Politics 36

6.1 Strategies: Goals, Tactics, and Conditions 36

6.1.1 Assets 36

6.1.2 Conditions 37

6.1.3 Goals 37

6.1.4 Tactics 37

6.1.5 Strategy Execution 38

6.1.6 What the Actor Knows, and When He Knows It 38

6.2 Support, Influence, and Control 39

6.2.1 Support 39

6.2.2 Influence 40

6.2.3 Control 40

6.2.4 When Control Shifts 41

7. Economics 42

7.1 Dollars 42

7.2 Sectors 42

7.3 Shape vs. Size 43

7.4 Economic Outputs 43

7.5 Neighborhood Aggregation/Disaggregation 44

7.5.1 Neighborhood Aggregation 44

7.5.2 Neighborhood Disaggregation 44

7.6 Ways to Affect the Economy 45

7.7 Effects of the Economy 45

8. Information 46

Part II: Using Athena 47

# Part I: Overview

## Introduction

This document presents the models and software of the Athena 3.1 Stability & Recovery Operations (S&RO) Simulation from the user’s point of view. Users are advised to read this document before moving on to the other Athena documents.

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

The intent of Athena’s models is first to capture and make explicit a wide variety of first order causal links, each of which makes sense on the face of it, and secondly to present the second and third order consequences of events while preserving the causal chain.

Everyone is familiar with the story of the ten blind men and the elephant. The goal of Athena is to model each of the elephant’s parts, and to link them together so that the man who has the elephant by the tail is sure to get thwacked by the elephant’s trunk (not to mention everything in between) and so must pay attention to the entire elephant.

### Overview of This Document

This document covers four major topics.

* Part I (Sections 1 through 8) describe the Athena models and philosophy at a conceptual level; those interested in more detail can see the low-level model descriptions in the *Athena Analyst’s Guide* and other documents.
* Part II (Sections TBD through TBD) describes the Athena application itself: the parts of the application, how to enter scenario data, how to run the simulation, and how to find the results.
* Part III (Sections TBD through TBD) contains a cookbook of how to make use of Athena’s models and inputs for particular problems.
* Part IV (Sections TBD through TBD) contains reference information, including a complete glossary of terms. Detailed reference information can be found in the Athena application’s on-line help.

### Other Documents

In addition to this user’s guide, Athena is delivered with the following documents:

*Athena Analyst’s Guide*

This document contains a detailed, low-level description of the models used in Athena; it serves as the specification document for the implementation of the models in the Athena code. Consult it when you need to know more about the models than is contained in this user’s guide.

*Mars Analyst’s Guide*

Mars is an infrastructure layer that is shared with the Joint Non-kinetic Effects Model (JNEM). The *Mars Analyst’s Guide* can be thought of as an appendix to the *Athena Analyst’s Guide* that describes the models that happen to be implemented in the Mars code base, including the Generalized Regional Attitude Model (GRAM) and the Mars Affinity Model (MAM). The former tracks direct and indirect effects on civilian attitudes; the latter models belief systems and the resulting affinities between actors and groups.

*Athena Rules Document*

This document describes the events and situations (drivers) that affect civilian attitudes in more detail than does this user’s guide, and also details each of the Driver Assessment Model (DAM) rule sets that assess the attitude change caused by the drivers.

*Athena On-line Help*

The Athena application includes extensive on-line help; see the **Help** menu in the application’s main menu bar. The most detailed reference information for the Athena software is found in the on-line help.

When Athena is installed on Microsoft Windows, these documents are available from the Athena folder on the Start Menu. Alternatively, go to the Athena application directory and open “docs\index.html” in a web browser. Documentation can also be obtained directly from the Athena Project; contact William.H.Duquette@jpl.nasa.gov.

### Changes for Athena 3

In its conception, Athena was intended to be a single-user version of JNEM customized and extended to be a decision support tool for courses of action in the S&RO environment. JNEM depended on an external federation of simulations for much of its simulation input, e.g., combat, civilian casualties, presence and location of military forces, and so forth. Athena versions 1 and 2 relied on the analyst for much of this input as the simulation ran. In particular, the analyst was expected to run Athena forward in short one month to three month time steps; at each pause, the analyst was to role play each of the relevant actors in the region, make appropriate inputs and adjustments, and then advance time again. This placed a great burden on the analyst.

The big change in Athena 3 is the addition of actors and their strategies. By defining the relevant actors and their strategies, the analyst can set up a complete scenario, and then let the modeled actors respond to the changing conditions. It is still possible for the analyst to pause frequently and make course-corrections if desired, but this is no longer an essential feature.

More specifically, in Athena 3 we have:

* Added actors and their strategies (goals, tactics, and attached conditions)
* Added the notion of *belief systems*; comparison of belief systems is the basis for the model of inter-group and group/actor relationships.
* Added a model of actor support, influence, and control of neighborhoods.
* Added a model of Essential Non-Infrastructure Services, which uses a new paradigm for driving attitude change.
* Revised the user interface:
  + Separated Scenario Mode from Simulation Mode. The data presented is now appropriate to the task being done. In particular, data populated only during simulation is now longer visible during scenario preparation.
  + Added the Detail Browser, a web-browser-like window for browsing the scenario and the simulation results.

## Athena Model Overview

Athena is a collection of many models that involve the relations and interactions between a several kinds of simulation object. This section gives a brief overview of the most important kinds of simulation object, and of the six major modeling areas. The various kinds of simulation object are documented in detail in Section 9; the modeling areas and the models they contain are described more fully in Sections 3 through 8, and are documented in detail in the *Athena Analyst’s Guide*, *Mars Analyst’s Guide*, and *Athena Rules* documents.

### The Simulation and its Objects

At its highest level, Athena models the actions taken by significant decision makers, called *actors*, within a region of interest, called the *playbox*. The playbox is divided into sub-regions, called *neighborhoods*. Each neighborhood is inhabited by some number of civilians, who are divided into *civilian groups*, and who form both the consumers and the labor force in the *local economy*.

The actors attempt to control, aid, or otherwise influence the civilians in the neighborhoods by means of their actions, which are called *tactics*. Executing tactics requires *assets*, of which there are two kinds: money and personnel. Each actor has an income, and may also own bodies of personnel, e.g., army troops, police forces, humanitarian relief organizations, and so forth. These are called *force groups* or *organization groups*, depending on the nature of the group. By attaching *conditions* to tactics, an actor can determine when and under what circumstances tactics are used. The collection of an actor’s tactics and conditions is called the actor’s *strategy*.

The civilian groups have *attitudes*: satisfaction or dissatisfaction with respect to particular, and a willingness or unwillingness to cooperate (i.e., share information with) members of force groups. These attitudes vary over time in response to the events and situations that occur in the simulation, including those triggered by the actors’ actions.

In addition, civilian groups can *support* actors to a greater or lesser degree. Support is based upon shared or compatible beliefs, but is also affected by actors’ actions and by conditions in the civilians’ neighborhoods. Members of force and organization groups also support the actor to whom the group belongs. Actors may use the support they receive, or lend it to other actors. An actor with sufficient support in a neighborhood is said to have *influence* in the neighborhood; and an actor with sufficient influence may *control* the neighborhood.

Thus, we have the following feedback loop:



The actors’ actions determine the situation on the ground, which in turn affects civilian attitudes. This in turn affects civilian support for the actors, which can cause a change in which actor controls each neighborhood. That political situation then drives the actors’ actions. There are, of course, smaller feedback loops within this one; for example, an actor can increase his support in a neighborhood by moving a significant military force into that neighborhood. The force supports him, possibly enough so that he gains control, bypassing (at least temporarily) civilian attitudes altogether. Similarly, there is a feedback loop from the situation on the ground back to the actors’ actions—even politicians look at more than just the latest polls. But at a high level, this is the dynamic that drives Athena execution.

The primary outputs at the end of an Athena run are these:

* The actor in control of each neighborhood
* The stability and security of each neighborhood
* The civilian groups’ attitudes about the state of the playbox
* The resources decisions required by each actor to bring about this end state.

Thus, Athena can be used both to analyze an existing political situation and to assess the results of various courses of action designed to change it, from the point of view of any or all of the actors involved.

### The Six Modeling Areas

Athena’s models fall loosely into six broad areas; the borders between these areas are often fuzzy, and some of the Athena models straddle them. The six areas are as follows:

**The *Ground* Area**

Literally, where things are on the ground, the things they are doing, and what is happening to them as a result. (Section 3)

**The *Demographics* Area**

This area concerns where civilians live and how many of them there are, along with the computation of such population statistics as the number of consumers in the local economy. (Section 4)

**The *Attitudes* Area**

This area deals with the attitudes of the people in the playbox, especially their satisfaction and cooperation levels, but also their belief systems and the relationships between the various groups in the playbox. (Section 5)

**The *Politics* Area**

This area deals with actors and their strategies (goals, tactics, and attached conditions) along with the determination of support, influence, and neighborhood control. (Section 6)

**The *Economics* Area**

This area deals with the local economy, relating changes in population and production to the consumer price index (CPI) and the unemployment rate. (Section 7)

**The *Information* Area**

This area deals with information flow in the playbox, and especially the effect of information flow and information campaigns on attitudes and politics. (Section 8)

The models in each of these areas are inter-related: every area depends on inputs and outputs from the other areas, as shown in the following figure. It is necessary to track all of them to get a complete view of the simulation.



Each of these areas and the models contained within it are described in the referenced sections; for full details on the models, see the *Athena Analyst’s Guide*, *Mars Analyst’s Guide*, and *Athena Rules* documents.

## Ground

The Ground Area is quite literally concerned with what is happening on the ground: where people are, and what they are doing, and the results of their actions. It includes:

* The breakdown of the playbox into neighborhoods and the relationships among the neighborhoods.
* Where civilian, force, and organization personnel are located
* The activities that they are performing, including combat activities
* Neighborhood security levels
* Activity coverage
* Environmental situations
* Essential Non-Infrastructure (ENI) services
* The Athena Attrition Model (AAM)
* Where production capacity is located.

Events and situations occurring in the Ground Area affect civilian attitudes, and the demographics and production capacity of the playbox and hence the economy as well. Actors base their decisions on the state of affairs in the playbox.

### Simulated Time

Athena measures the passage of time in integer days. It is a time-step simulation, with a step-size of one day; however, most simulated happenings take place week-by-week, e.g., combat attrition is assessed once each week.

### The Playbox

The playbox is the geographic area in which the simulation takes place. It is modeled as a collection of polygonal regions called *neighborhoods*, which are laid out on a map. In Athena 3, the neighborhoods are simply convenient bins for collecting simulation objects that are near each other; the layout of neighborhood polygons on a map is simply an aid to visualization.

#### Neighborhoods

Almost everything that happens in Athena takes place in the context of a neighborhood. Civilian groups reside in neighborhoods; force and organization group personnel are deployed to neighborhoods; personnel and actors act in neighborhoods; attitudes and output statistics are measured in neighborhoods.

Neighborhoods can be of any size, from portions of a city (neighborhoods in the proper sense of the word) to entire cities, counties, districts, provinces, countries, or groups of countries. Neighborhoods can nest, i.e., a neighborhood representing a city can be placed on top of a neighborhood representing a province.

Each neighborhood can be more or less urbanized, and can contain more or less of the playbox’s economic production capacity.

#### Neighborhood Proximity

Neighborhoods are simply bins; the geographic layout of the neighborhoods on the map has no effect, in and of itself, on the simulation results. It is clear, however, that some neighborhoods are more closely related than others. Because this is a social distance, not a physical distance, we model it directly rather than deriving it from the geography.

We call this social distance *neighborhood proximity*; it is defined as the distance between two neighborhoods from the point of view of the residents of the first neighborhood. More specifically, we say that with respect to neighborhood A, neighborhood B is near, far, or remote. The degree to which A is affected by events in B tapers off with distance, and is zero if B is remote.

Proximity need not be symmetric. If neighborhood A contains popular destinations, it might be considered nearby by neighborhoods which its residents consider to be far away.

#### Neighborhood Effects Delay

Events and situations occurring in the Ground Area drive attitude change. Such drivers usually have a direct effect in a single neighborhood, but may have indirect effects in other neighborhoods. Athena 3 allows these indirect effects to be delayed by some number of days, to reflect the spread of the news across the playbox.

This portion of the model was inherited from JNEM, and makes good sense in a scenario where events are occurring minute by minute, hour by hour. In Athena, events take place day by day, and more usually week by week. The effects delay makes much less sense at this timescale, and in an era of modern communications and transport; consequently, it is likely to be removed in a future version.

#### Local vs. Non-Local Neighborhoods

**TBD: Should this go in the Economics section?**

Athena assumes that the neighborhoods that make up the playbox are more or less and contiguous and have a single more or less unified economy. Sometimes, however, it can be convenient to include neighborhoods neighborhoods in the scenario that are outside the economy. Pakistan is greatly affected by the decisions made by actors in India, for example; in a scenario involving the inner workings of Pakistan, it might be desirable to include India as a neighborhood while excluding India from the modeled economy. Thus, we can mark neighborhoods as *local* (participants in the local economy) or *non-local* (excluded from the local economy).

#### Production Capacity

**TBD: Should this go in the Economics section?**

The Economics model assigns production capacity (e.g., factories, farms, and other businesses) to neighborhoods at time 0 based on the size of the economy in dollars and the size of the labor force in each neighborhood. Each neighborhood is then assigned a production capacity factor (PCF) of 1.0 that reflects this initial production capacity. The PCF of a given neighborhood can be increased or decreased over time by actors or by the analyst to reflect construction of new facilities or damage to infrastructure, thus increasing or decreasing the production capacity of the economy as a whole.

Note that the costs associated with repairing, replacing, or building new production capacity are not modeled, nor is the nature of the required plant or the training of the labor force.

### Actors

*Actors* are significant decision makers in the playbox. Depending on the needs of the scenario, an actor may be an individual, a committee, a small group, a ruling body, or an entire country. The essential point is that an actor has:

* Goals it wishes to achieve
* A strategy for achieving them
* Assets to use to achieve them.

In Athena 3, actors have income, which can be spent in a variety of ways, and can own force and organization groups which they can make use of.

Actors can have different domains—military, political, economic, cultural—and although these domains are implicit in the actor’s assets and strategies rather than explicit in the model, they are no less important for all that.

Most actors participate in the political process, seeking control of neighborhoods or supporting those who do. Organization groups, which usually do not play politics in the playbox, are often owned by a “pseudo-actor”, an actor that supports no one politically and exists only to hold the strategy that determines organization group behavior.

There is an additional pseudo-actor, or *agent*, the **SYSTEM** agent. The **SYSTEM** agent is not an actor, and cannot be involved in politics; however, it does have a strategy, which allows the analyst to set up various events and situations to occur when conditions in the simulation are right. In particular, the **SYSTEM** agent is responsible for displacing civilians to other neighborhoods.

### Groups

Athena represents masses of human beings as *groups*. There are three kinds: *civilian groups*, *force groups*, and *organization groups*. Every group has a demeanor, **apathetic**, **average**, or **aggressive**, that indicates its propensity for violence.

#### Civilian Groups

The population of the playbox is broken down into a number of *civilian groups*. Each civilian group resides in a particular neighborhood, and has a *belief system* that gives it its identity (Section 5.1) and determines how it relates to other groups and actors. It also has greater or lesser *satisfaction* with the current state of affairs, and a greater or lesser *cooperation* with (willingness to give information to) the actors’ various force groups (Sections 5.4 and 5.5). Civilian groups support actors to a greater or lesser degree; ultimately, any successful actor must either derive his power in a neighborhood from the resident civilians, or expect to keep a significant body of troops in place.

In JNEM, and in earlier versions of Athena, it has been usual to think of civilian groups in ethnic terms, as clans, tribes, or related groupings of such. At the beginning of the Athena project, in particular, we expected each group to be a stovepipe containing individuals from cradle to grave. In Athena 3, by contrast, groups are collections of people living in the same area who share a belief system. When an ethnic grouping contains significant divisions, e.g., a “generation gap”, it may be prudent to split the ethnic grouping into multiple groups. Similarly, if a particular belief system cuts across ethnic groups, it may be wise to treat it as a single group.

At present, individuals cannot move from one group to another group. In future versions of Athena we might support this, as a way of indicating the erosion of one belief system in favor of another.

#### Force Groups

A *force group* is an organized group of personnel intended to project and use force in a neighborhood. Force groups belong to actors, and do their bidding according to the actor’s strategies. In particular, an actor can increase his support in a neighborhood by moving his troops into that neighborhood. There are five kinds:

* Regular military
* Irregular military (e.g., militias)
* Paramilitary (e.g., SWAT teams, militarized police forces)
* Police
* Criminal

Each force type has a different force multiplier; regular military, for example, is much better at projecting and using force than normal police.

Force groups can carry out military duties of various kinds, and can also participate in humanitarian relief efforts (Sections 3.5 and 3.11.1).

Each force group starts the scenario with a certain number of troops, which can increase and decrease as the simulation runs. At present, force groups cannot recruit from the civilian population, though this is an area in which we are actively working.

Force groups do not have belief systems of their own; rather, they inherit them from their owning actors.

#### Organization Groups

Organization groups are similar to force groups, but have some mission other than the projection and use of force. There are three kinds:

* Non-Governmental Organizations (NGOs), e.g., Doctors Without Borders
* Inter-Governmental Organizations (IGOs), e.g., UNESCO
* Contractors, e.g., Halliburton

Like force groups, members of organization groups can be assigned activities in neighborhoods, though they are limited to humanitarian relief activities of various kinds. In principle organization groups can support the political goals of actors by their presence in one neighborhood or another; however, organization groups are usually owned by pseudo-actors who are not politically active.

### Deployment

Every person in the playbox has to be somewhere, i.e., has to be located in some neighborhood. Civilians are simply located in their home neighborhoods (unless displaced; see Section 3.4); force and organization group personnel need to be *deployed* to particular neighborhoods.

As the simulation progresses, deployment is determined by the tactics chosen by the actors; see Section 6. It is also necessary to know where force and organization group personnel were located prior to the start of the simulation; this is called the *status quo deployment*, and is a scenario input.

Troops are deployed by their owning actors during strategy execution, and remain in place throughout the week until the next strategy execution.

### Activity Assignment

Force and organization group personnel deployed to a neighborhood can be assigned activities in that neighborhood: patrolling, guarding, law enforcement, various kinds of humanitarian relief, and so forth (see Section TBD for the complete list, and a description of each). These activities affect the attitudes of the civilian population. Activities are assigned by the actors during strategy execution, and like deployments take place over the following week.

Force and organization group activities have security requirements; a body of troops might be tasked to do humanitarian relief of some kind, but if they have insufficient security in the neighborhood their efforts will be of no avail. (See Sections 3.6 and TBD.)

Civilians are displaced by assigning them the **DISPLACED** or **IN\_CAMPS** activities, which are assigned not by actors but by the System agent; see Section TBD.

### Units

All deployed personnel, and all civilian personnel, are placed in *units*. The name derives from the classic military term; in Athena it simply means a collection of personnel belonging to the same group and assigned the same activity. Units have no distinctive or long-running identity; they are created during strategy execution and represent the location and activity of group personnel over the following week. If personnel from force group A are deployed to neighborhood B, and assigned various activities, then A will have at least one unit for each activity, plus an additional unit for those personnel that remain unassigned.

Units are useful for visualization; and many of the subsequent models in the Ground Area operate on units.

### Volatility and Security

A neighborhood can be a safe or unsafe place to be for the people within it—and to a great extent, that depends on who they are and who is in the neighborhood with them. Athena computes two measures, the *volatility* of each neighborhood and the *security* of each group in each neighborhood.

Both depend on the personnel in the neighborhood and in nearby neighborhoods, and on their relationships with each other (see Section 5 for more on relationships).

First, each group in the neighborhood (whether civilian, force, or organization) can project a certain amount of force, given the kind of group it is and the number of personnel present. This is its power to defend itself. Civilian groups project minimal force per person, given that civilian groups include the very old and the very young, and many adults who are not inclined to project force. Force groups exist to project force, and do it rather better; their effectiveness depends on the kind of force they are. Regular military projects the most force per person. Of organization groups, only contractors project any force (private security guards)—more than civilians but less than any force group. (See Section TBD for more on the different kinds of group.)

But a group’s ability to defend itself does not depend solely on its own force—they may have friends to help them; and unless they have enemies they will not need to defend themselves. Athena totals up the force available to each group, including friends in the same neighborhood and (to a lesser degree) friends in nearby neighborhoods; and similarly it totals up the force available to the group’s enemies in the same neighborhood and (to lesser degree) in nearby neighborhoods.

The *volatility* of a neighborhood ranges from 0 to 100, and is a measure of how dangerous the neighborhood is to a random passerby given the degree of enmity present in the neighborhood, i.e., how likely a person is to get caught up in random violence that does not directly concern him.

Danger to a group comes from its enemies and from the kind of random violence measured by volatility. We capture this as the *security* of the group in the neighborhood. Security is an abstract measure ranging from -100 to 100. For actual use we convert it to a qualitative measure (high, medium, low, or none), or to a multiplicative factor using a Z-curve function.[[1]](#footnote-1)

In Athena 3, *volatility* is primarily a component of *security*, whereas *security* affects many things, including:

* Whether force and organization groups can carry out particular activities in a neighborhood.
* The degree to which groups can actively support the actors of their choice.

The addition of a military force to a neighborhood can greatly change the security of all groups in the neighborhood. In Athena 3, this change is due purely to the number of troops and the relationship between the force group and the other groups in the neighborhood: the security of the force group’s enemies will decrease, and the security of the force group’s friends will increase.

Consequently, further work needs to be done here; a force assigned peacekeeping duties should have a different effect than a group intending rapine and pillage.

### Coverage

*Coverage* is a measure, from 0.0 to 1.0, of the fraction of a neighborhood or group affected by some situation. The notion of coverage is used in a number of places in Athena:

* Environmental situations are assigned a coverage when they are created. (Section 3.9)
* Coverage is computed for the mere presence of a military force deployed in a neighborhood.
* Coverage is computed for activities assigned to groups of all kinds. (Section 3.4)

For environmental situations, the coverage is simply an input. For presence and activities, it is a function defined by the number of troops required to achieve 2/3rds coverage given the size of the population. For presence, for example, presence coverage is 2/3rds when there are 25 troops present for each 1000 people in the civilian population. Coverage drops to zero when there are no troops present or engaged in the activity, and increases asymptotically to 1.0 as troops are added above the 2/3rds mark.

Assigned activities usually have a security requirement. If there are 25 troops per 1000 people assigned to do the “CMO – Healthcare” activity, but the security of those troops is low, they cannot carry out the activity effectively and hence the coverage of that activity by those troops is 0.0.

The coverage fraction is used as a multiplier in the relevant rule set in the Driver Assessment Model (Section 5.6); and presence coverage is used in a variety of places, most notably in the Athena Attrition Model (Section 3.10).

### Activity Situations

When a group is conducting an activity of a particular type in a neighborhood with coverage greater than 0.0, we have what we call an *activity situation*,[[2]](#footnote-2) or “actsit”. Activity situations are created when coverage exceeds 0.0, and are destroyed when coverage returns to 0.0. So long as the situation persists it will have affects on civilian attitudes as determined by the relevant rule set in the Driver Assessment Model; see Section 5.6 and the *Athena Rules* document.

Force and organization group activities can mitigate particular environmental situations, e.g., the “CMO – Healthcare” activity will have a greater effect on civilian attitudes when there is a “Disease” environmental situation in the neighborhood.

### Environmental Situations

*Environmental situations*, or “ensits,” represent problems in a neighborhood’s environment that adversely affect the resident civilians, e.g., power outages and food shortages; see Section TBD for the complete list.

Environmental situations are usually created by the analyst, or by actors using the **EXECUTIVE** tactic. An ensit will typically have a big negative effect on satisfaction on inception, a continuing negative effect so long as the situation persists, and a big positive effect when the situation is resolved.

The duration of an ensit can be set when the ensit is created; it can also be resolved explicitly by the analyst or by an actor using the **EXECUTIVE** tactic. Each ensit also has a coverage fraction, nominally 1.0, which can be decreased to decrease the ensit’s effects.

The effect of certain environmental situations can be mitigated by appropriate force and organization group activities, as indicated in the *Athena Rules* document.

The environmental situation model is one of the oldest parts of Athena, being adopted with minimal changes from JNEM. It was designed for five-day real-time training exercises with the intent of rewarding commanders for quick resolution and punish them for delayed or omitted resolution of the problems represented by the ensits. As such, it will tend to run “hot”; when ensits are used in an Athena scenario, the analyst should monitor them closely, and should consider using smaller coverage fractions to reduce the effects if they are overstated.

In the future, it is likely that many of the existing ensit types (e.g., power outages) will be replaced by service-oriented models like the current Essential Non-Infrastructure (ENI) Services model (Section 3.11), which is more suited to the Athena time frame.

### Athena Attrition Model

Athena was designed to support Stability and Recovery Operations (S&RO); i.e., to model regions in which the heavy metal force-on-force battles are over (or have not yet begun). Thus, Athena 3 does not model full-on force-on-force attrition. Rather, it deals with two kinds of conflict: the efforts of conventional uniformed forces to hunt down and kill non-uniformed insurgent/terrorist forces, and the efforts of these non-uniformed insurgents and terrorists to use guerilla tactics against the uniformed forces. Such combat results in attrition to the relevant forces, thus reducing their numbers in the playbox, and also in civilian collateral damage with the relevant effects on civilian attitudes.

In short, uniformed forces can seek to attack non-uniformed forces, and non-uniformed forces can seek to attack uniformed forces, neighborhood by neighborhood.

#### Rules of Engagement

Whether force group A seeks to attack force group B in neighborhood N is determined by A’s rules of engagement (ROE), which are set according to the strategy of the actor that owns group A. Using the **ATTROE** tactic, the actor can direct that A may attack B in neighborhood N up to some number of times over the next week. If A is a non-uniformed group, then the actor may also specify whether A is to minimize its own losses or maximize damage to B.

In the current model, civilian collateral damage occurs when a uniformed force attacks a non-uniformed force, and when a uniformed force defends itself against attack by a non-uniformed force. Thus, uniformed forces also have a defending ROE in each neighborhood, which determined whether and how quickly they fire back at attacking non-uniformed forces. This directly affects the quantity of civilian casualties.

#### Presence and Intelligence

Just because force group A has been directed to attack force group B in neighborhood N, it is not certain that it will be able to. Whether attacks occur or not depend on a number of circumstances:

* Both A and B must have troops in neighborhood N.
* The more troops A has, the more likely it is to be able to find and attack B.
* The more troops B has, the more easy it is to find.
* Intelligence, as indicated by the cooperation of the neighborhood with both groups, also plays a role.
  + If A gets better cooperation than B, it will have an easier time finding and attack B.
  + If A gets worse cooperation, then it will have a harder time.
  + If A is a non-uniformed force, then the expected losses must be acceptable, and this also depends on the quality of the intelligence received by A, as indicated by the neighborhood cooperation.

Cooperation is discussed in Section 5.5.

#### Attrition Assessment

The number of successful attacks by all parties, and the resulting civilian casualties, are assessed at the end of each week just prior to the next strategy execution. The casualties are then given to the Driver Assessment Model (Section 5.6) so that the attitude changes can be assessed.

#### Magic Attrition

The Athena Attrition Model does not address terror bombings, assassinations of political figures, or deaths due to other kinds of armed combat than those described above. And yet, these kinds of deaths occur. For this reason Athena provides the ability to do “magic attrition,” which can be initiated by the analyst, or by an actor or the **SYSTEM** agent using the **EXECUTIVE** tactic. Magic attrition can affect members of any group; and in particular, civilian casualties will be assessed by the Driver Assessment Model just like casualties resulting from the kinds of combat Athena *does* model.

Note that magic attrition should not be used for civilian deaths due to natural disasters, epidemics, or other causes that do not involve combat. For those kinds of things, the attitude effects should be handled by either environmental situations (Section 3.9) or magic attitude drivers (Section 5.7).

### Essential Non-Infrastructure (ENI) Services

Essential Non-Infrastructure (ENI) Services are services provided to civilians in a neighborhood by an actor, the absence of which causes hardship but which do not require substantial infrastructure to provide. Provision of services is controlled by the actor’s strategy, and can be targeted to specific groups in the neighborhood, ignoring others.

#### The Notion of a Service

A service is something provided to the civilians (possibly by their own efforts, as enabled or supported by actors) that has a level that can increase or decrease over time. Examples are power service, postal service, communications, water supply, the court system and other governmental services, and the like (though not law enforcement, as that’s an assigned activity). We call the level of service for a particular service the *LOS*. For any given service there are four specific levels of service that are of interest:

**The Actual Level of Service (ALOS)**

How much of the service is the group actually receiving at the present time?

**The Required Level of Service (RLOS)**

How much of the service does the group need to live without significant hardship?

**The Expected Level of Service (ELOS)**

How much of the service is the group accustomed to getting?

**The Saturation Level of Service (SLOS)**

What’s the level of the service which saturates the demand? Once the civilians have all they want, they don’t care if more is available.

The units appropriate for measuring a particular the level of a particular service will vary from service to service.

The expected level of service will slowly approach the actual level of service over time; in other words, the civilians will eventually become accustomed to whatever level of service they receive. Expectations will rise more quickly than they will fall: we become accustomed to good things more quickly than we become resigned to bad things.

For example, in most of America ELOS for the power supply simply *is* the SLOS. We most of us have all the power we are willing to buy. If the power is out, we are immediately unhappy, and would takes us quite a while to get used even to power provided on a regular if intermittent schedule; but when the power goes back on, we get used to it with great rapidity.

Civilian attitudes improve when the ALOS is greater than expected (though not more than the SLOS), and worsen when the ALOS is less than expected, and especially if it is less than required.

There are four cases of particular interest:

* Case R-: Service is less than required
* Case E-: Service is less than expected
* Case E: Service meets expectations
* Case E+: Service is better than expected

Note that case R- trumps all of the others; and that case E+ can only occur if the expected level of service is less than saturation.

At the present time we have used this paradigm only for ENI services; we expect to make use of it for infrastructure-based services in the future.

#### Services vs. Environmental Situations

As such, the service paradigm is an improvement over the Environmental Situation paradigm for services like the power system and the water supply. Using the power system for illustrative purposes, the ensit paradigm implicitly assumes that the ALOS is normally at its expected value, and that when problems occur it drops down to 0.0. Horrors ensue until the problem is resolved, at which point it service returns to its previously expected level.

In a long-run scenario, however, it is quite possible that the power service may be substandard (though not zero) for quite long periods of time. Power for 12 hours a day is much better than no power at all; and after a few weeks’ time, the civilians will begin to adjust to it (and the attitude effects will cease). If power then drops to 4 hours a day, they will again react negatively; but if it returns to 24 hours a day they will react positively.

We expect service-orient models to replace many of the existing ensit types as time goes on.

#### Measurement of ENI Services

Actors provide ENI services to groups in neighborhoods by spending money on them using the **FUNDENI** tactic. No infrastructure is required, by definition; and we assume that every dollar spent translates (not necessarily linearly) into service provided.

For convenience, we measure the provision of ENI services to a group in a neighborhood as a fraction of the saturation level of service (SLOS) for that group: 0.0 implies no service, and 1.0 implies the saturation level of service. Then, we specify the saturation level of service by the per capita funding required to achieve it. If actors provide funding for more than the saturation level of service, the ALOS will be greater than 1.0.

#### Required Level of ENI Services

The required level of ENI services is set in the model parameter database as a fraction of the saturation level of service, according to the urbanization level of the neighborhood.

#### Status Quo ENI Funding

The level of ENI service provided to a particular group depends on the actor’s strategies; but how the actors execute their strategies depends on the current state of affairs, which includes some level of spending on ENI Services. Thus, we need to know the funding for ENI services prior to time 0; this is a scenario input called the *status quo ENI funding*.

#### Effects of ENI Services

The current level of ENI services affects two things:

* Civilian satisfaction levels; see Section 5.6.
* The vertical relationships of civilian groups with actors; see Section 5.3.

In each case, the fundamental questions are whether the civilians are receiving the required level of service; and if so, whether they are receiving more or less service than they expect.

In terms of the vertical relationships, it also matters whether or not the actor providing the service has control of the group’s neighborhood; see Section 5.3 (and the *Athena Analyst’s Guide*) for details.

## Demographics

The Demographics Area is closely tied to the Ground Area, as it is concerned with how many civilians there are and where they live. The Demographics model proper is responsible for determining the current population (by group, neighborhood, and playbox), as well as the size of the labor force, the number of consumers in the local economy, and similar population statistics. In addition, the Demographic Situation (demsit) model determines the effects of unemployment on each civilian group, which in turn drives attitude change.

### Base Population

The population is divided into civilian groups (Section TBD); each civilian group resides in a neighborhood. At time 0, each civilian group has an initial or *base* population. The base population of the neighborhood is simply the total across the civilian groups, and the base population of the playbox is simply the total across the neighborhoods. Note that we also track the total population of local neighborhoods (Section 3.2.4), because that figures into the Economics Area.

### Current Population

The *current population* of civilian groups and of neighborhoods can change over time. Athena does not model births or natural deaths, but it does model deaths due to civilian collateral damage (Section TBD). The Demographics model tracks attrition to date, subtracting it from the current population. In addition, civilian group personnel can be *displaced* to other neighborhoods (Section TBD), which removes them from the current population of their group and neighborhood, and adds them to the current population of the neighborhood to which they are displaced.

### Subsistence Agriculture

Civilian personnel can support themselves by *subsistence agriculture* or by participating in the local economy. In Athena 3 there is a hard line between the two: any given person is in one subset or the other. The percentage of each civilian group that lives by subsistence agriculture is a scenario input.

When civilians belonging to a group are displaced from their home neighborhood, it is presumed that subsistence and non-subsistence personnel are displaced in proportion to the size of the two subsets within that group. If they later return to their homes, they resume their previous ways of life.[[3]](#footnote-3)

Because subsistence personnel do not (by definition) participate in the local economy, they are neither consumers nor members of the labor force. As a result, they are not directly affected by high unemployment rates.

### Consumers and Workers

All non-subsistence-agriculture personnel are presumed to be *consumers* in the local economy;[[4]](#footnote-4) the total number of consumers drives the size of the economy.

In each group, only a percentage of the consumers (nominally 60%) are members of the *labor force*. For civilians displaced from their homes, whether they remain within their own neighborhood or are displaced to another neighborhood, the percentage drops to 40%. Displaced civilians who are settled in camps do not contribute to the labor force at all.

### Demographic Situations

*Demographic situations* are situations detected by the Demographic model that affect the attitudes of the civilians. Athena 3 defines only one demographic situation, or “demsit”, the Unemployment situation.

The unemployment rate is computed for the entire playbox by the Economics model. It affects civilian groups in proportion to the number of workers in each group. Given that, high unemployment affects civilians in two ways:

* Directly, by economic hardship to members of the group. Groups with a high Subsistence Agriculture Percentage are relatively immune to this.
* Indirectly, by the presence of numbers of unemployed workers in the neighborhood.

See the *Athena Rules* document for specifics.

## Attitudes

The *Attitudes Model* deals with the attitudes of the people in the playbox, and particularly:

* The belief systems of each of the actors and civilian groups
* The horizontal relationships between groups
* The vertical relationships between groups and actors
* The satisfaction of the civilian groups with respect to various concerns
* The cooperation (i.e., willingness to share information) of the civilian groups with respect to the force groups.
* Assessment of the effects of events and situations in the other models on the attitudes.

Note that the term “attitudes” properly applies to satisfaction and cooperation levels, which are managed by the Generalized Regional Attitudes Model (GRAM) (see the *Mars Analyst’s Guide*). However, the relationships (which derive from the belief systems, among other things) are also attitudes in a wider sense.

### Belief Systems and Affinities

Every civilian group and actor has a *belief system*, a statement of the ideas and issues that are important to the group or actor, along with how important they are and how the group or actor feels about those who disagree. For a civilian group, the group’s belief system is the source of the group’s identity and the basis for its relations with all other groups. An actor’s belief system may indeed reflect the actor’s deeply held beliefs, or it may be a construct intended to garner support from the civilians.[[5]](#footnote-5)

Given the belief systems of two entities, A and B, we compute the *affinity* of A with B, and of B with A. The affinity is a number from 1.0 down to -1.0 that indicates whether A supports or opposes the same things as B. Note that affinity need not be symmetric.

All horizontal and vertical relationships in Athena are ultimately based on affinities, and hence on belief systems.

Belief systems and affinities are computed by the Mars Affinity Model (MAM), which is documented in the *Mars Analyst’s Guide*.

#### Beliefs and Topics

A belief system consists of an entity’s beliefs about one or more topics. A topic is some value, principle, or issue about which there is some disagreement in the playbox. In Pakistan, for example, Islam is a significant fault line between the Pakistani citizens and the United States. Topics are chosen by the analyst; there is no default set.

A belief consists of two values, the entity’s *position* for or against the topic of interest, sometimes known as the *zeal*, and the entity’s *emphasis* on agreement or disagreement with that position. The former indicates how much the entity cares, and the latter determines how it feels about those who agree or disagree.

The position and emphasis are usually entered qualitatively, using the following values. For position, the entity may be:

* **Passionately For (P+)**
* **Strongly For (S+)**
* **Weakly For (W+)**
* **Ambivalent (A)**
* **Weakly Against (W-)**
* **Strongly Against (S-)**
* **Passionately Against (P-)**

The entity may put its emphasis on agreement or disagreement, as follows:

* **Agreement—Strong**
* **Agreement**
* **Neither**
* **Disagreement**
* **Disagreement—Strong**
* **Disagreement—Extreme**

If the emphasis is on agreement, the entity will tend to have a higher affinity with those entities with whom it agrees on this topic, while to some extent disregarding disagreements. If the emphasis is on disagreement, the entity will tend to have a lower affinity with those with whom it disagrees on this topic, while to some extent disregarding agreements.

Note that strong beliefs do not thereby imply a propensity to use violent action (though they may engender violent action in those groups that are so inclined). Propensity to violence is driven by a group’s *demeanor*; see Section 3.4. For example, I might be passionately in favor of chocolate ice cream, and greatly dislike anyone who passionately dislikes chocolate ice cream without being inclined to take violent action against the chocolate ice cream haters. It depends on my demeanor.

Levity aside, a strong position and emphasis on a topic *does* indicate some willingness to take action. It simply does not indicate a propensity for violence.

#### Affinity

The affinity between two entities is computed by comparing their beliefs on each topic, and tallying the effects of their agreements and disagreements given their positions and emphases.

As stated above, affinity is a number from -1.0 to 1.0 that is used as the basis for computing relationships.

Affinity is computed when the scenario is locked and simulation begins; in Athena 3 it is constant thereafter. In future versions we expect to allow it to vary.

#### Playbox Commonality

Selecting the relevant set of topics for a given playbox is more of an art than a science, and by the nature of things the tendency is to accentuate the negative—it is simply more easy to identified fault lines rather than the significant areas of agreement. When commonality is ignored, however, the resulting affinities tend to indicate that all parties concerned hate each other with a deep and abiding hatred.

The Mars Affinity Model handles this using the *playbox commonality* slider, a numeric factor nominally set to 1.0. We assume that the entities in the playbox have significant commonality, and in fact generally agree on about as many things as they disagree. More specifically, for each topic entered by the analyst, we add an implicit pseudo-topic of general agreement.

The number of these pseudo-topics is determined by the slider. If it is set to 1.0, there are as many pseudo-topics as real topics. If it is set to 2.0, there are twice as many; if it is set to 0.5, there are half as many. Moving the slider up and down will tend to move affinities up and down accordingly.

#### Entity Commonality

The playbox commonality lets you establish the degree of belief that is generally common to all groups in the playbox. But in fact, different entities will share in that common pool of belief to different extents, and foreign groups and actors will often have significantly different beliefs. Consequently, each group and actor has an *entity commonality* slider: a number from 0.0 to 1.0 that indicates the extent to which the entity participates in the general consensus indicated by the playbox commonality. If the entity commonality is 1.0, the entity shares the general consensus completely; if 0.0, not at all.

Decreasing an entity’s entity commonality will tend to decrease the entity’s affinity with other entities.

### Horizontal Relationships

Every group, whether civilian, force, or organization, has a horizontal relationship with every other group. The relationship is represented as a number for -1.0 to 1.0, where 1.0 indicates that the groups are bosom friends (every group automatically has a relationship of 1.0 with itself) and -1.0 indicates that the groups are the bitterest of enemies. The realistic range is from about -0.8 to about +0.8.

In Athena 3, these relationships are simply equal to the relevant affinities, and are constant for the duration of the simulation. Force and organization groups do not have belief systems, but they are owned by actors that do; and for the purpose of computing horizontal relationships we simply presume that they inherit the belief systems of their owners.

This horizontal relationship is one of the most basic concepts in Athena, and has significant effects across the entire simulation.

#### Relationship Overrides

Every computed horizontal relationship can be overridden by an analyst’s preferred value during scenario preparation.

### Vertical Relationships

Groups have vertical relationships with actors. Unlike horizontal relationships, which are bidirectional (though asymmetric), vertical relationships are unidirectional—that is, we measure each group’s relationship to each actor, but not the actor’s relationship to each group. Actors are what they do, and what they do is determined by their strategies, not by their affinities.

Like horizontal relationships, vertical relationships are measured from -1.0 to 1.0, a range which is often expressed qualitatively:

* Supports
* Likes
* Is Indifferent To
* Dislikes
* Opposes

Vertical relationships play a major role in the political model, for they are the basis for computing each actor’s support and influence and for the determination of neighborhood control (Section 6.2).

#### Force and Organization Groups

Every actor has an affinity for every other actor, and every force and organization group is owned by an actor. A force or organization group’s vertical relationship with its owner is always 1.0, and its vertical relationship with any other actor is simply its owner’s affinity for that actor.

#### Civilian Groups

The vertical relationship of a civilian group with an actor is rather more complicated, as it can vary dynamically as the simulation runs. It is based on the affinity of the group for the actor, but this is adjusted by a number of factors:

* Whether the actor is or is not in control of the group’s neighborhood
* How the group’s mood (see Section 5.4) has changed
* Whether and to what extent the actor is providing Essential Non-Infrastructure (ENI) services to the group

The baseline for assessing these factors is the start of the simulation; or, later on, the time at which control of the neighborhood last shifted—an actor newly in control is judged on the state of affairs on his watch, rather than his predecessor’s.

Future versions of Athena will probably take additional factors into account:

* Tactics chosen by the actor, and how they accord with the group’s belief system
* Changes in the group’s or actor’s belief systems, resulting in a change in affinity.

### Satisfaction Levels

Every civilian group has a sense of satisfaction or dissatisfaction with the state of affairs in the playbox. Satisfaction in this sense is not a feeling, *per se*, though we often use the language of feelings and take about the group’s “mood” or say that the group “likes” or “dislikes” some event or situation. Rather, dissatisfaction is the will to change the current state of affairs, and satisfaction is the will to preserve the current state of affairs.

Satisfaction is measured as a number from 100.0 to -100.0, where 100.0 is perfectly satisfied and -100.0 is utterly dissatisfied.

The initial satisfaction levels are set by the analyst during scenario preparation; once simulation begins they vary depending on the events and situations that occur (Section 5.6).

#### The Four Concerns

We measure satisfaction on four axes, called the four *concerns*, also known as the four *soft factors*:[[6]](#footnote-6)

**Autonomy (AUT):** Does the group feel that it can maintain order and govern itself with a stable government and a viable economy?

**Safety (SFT):** Do members of the group fear for their lives, either from hostile attack or from collateral damage from force activities? This fear includes environmental concerns such as life-threatening disease, starvation, and dying of thirst.

**Culture (CUL):** Does the group feel that its culture and religion, including cultural and religious sites and artifacts, are respected or denigrated?

**Quality of Life (QOL):** QOL includes the physical plants that provide services, including water, power, public transportation, commercial markets, hospitals, etc., and those things associated with these services, such as sanitation, health, education, employment, food, clothing, and shelter.

#### Saliencies

Each group has a *saliency* for each concern: a number from 1.0 to 0.0 that indicates how important that concern is to the group, where 1.0 is crucial and 0.0 is negligible.

#### Group Mood

A group’s *mood* is the average of its four satisfaction levels, weighted by the group’s saliency for each concern. Mood is a convenient summary statistic, and is an input to a number of other models.

### Cooperation Levels

Civilian groups are more or less willing to share information with members of force groups. Following standard HUMINT terminology, this willingness is called *cooperation*, and each civilian group is said to have a *cooperation level* with respect to each force group. The cooperation level is a number from 0 to 100, and represents the probability that a member of the civilian group will give information to a member of the force group.

Like satisfaction levels, cooperation levels are initialized during scenario preparation and vary thereafter based on the events and situations that occur (Section 5.6).

Note that having a high cooperation does not imply that the civilian group will overtly aid the force group in any way—they might or might not.

### Trends and Thresholds

Each satisfaction and cooperation curve has associated with it an ascending trend and threshold, and a descending trend and threshold; these allow the curve’s value to regress to a mean value, or at least a mean range. A trend is simply a slope effect (Section TBD) that is applied to the curve each day; the ascending trend increases the level, and the descending trend decreases it. Each is associated with a threshold. If the current level is above the ascending threshold, the ascending trend is ignored; if the current level is below the descending trend, the descending threshold is ignored.

For example, it might be reasonable to assume that a group’s satisfaction with Quality of Life (QOL) is 0.0 in the long term: the civilians get used to current conditions and don’t think about them one way or another. This can be modeled by setting an ascending trend with an ascending threshold at or just below 0.0, and a descending trend with a descending threshold at our just above zero. The ascending trend will then drive the current QOL level up to 0.0 and stop, and the descending trend will drive the level down to 0.0 and then stop.

All trends default to 0.0, and thus have no effect.

### The Driver Assessment Model (DAM)

The *Driver Assessment Model* (DAM) is responsible for assessing the satisfaction and cooperation effects of the various events and situations that occur in the simulation, e.g., civilian casualties (Section 3.12.3) and activity situations (Section 3.10). Collectively, these events and situations are called *drivers*. Athena contains a rule set for each kind of driver; the rule set assesses the driver, and gives *level inputs* and *slope inputs* (see below) to GRAM, which tracks satisfaction and cooperation effects as they play out over time. These rule sets are documented in detail in the *Athena Rules* document.

#### Level and Slope Inputs

A *level input* is a step change that takes effect over a short period of time, usually two days. A *slope input* is a slope (e.g., 5 points per day) that takes effect each day for the duration of a situation. Level inputs are usually used to model the effect of significant one-time events, and slope inputs are usually used to model the effect of on-going situations.

Both kinds of input have a *magnitude* which is applied to a particular curve.

#### Direct and Indirect Effects

Every level or slope input targets a specific curve: group A’s satisfaction with QOL, or group B’s cooperation with group C. This is called the direct effect. But other groups are affected as well. If group A takes casualties, for example, the satisfaction of the other groups in the neighborhood will be affected as well. This is called an indirect effect, and it is usually modified by the relationship between the groups.

Indirect effects can occur in the same neighborhood, in nearby neighborhoods, and in far-away neighborhoods (see Section 3.2.2 for a discussion of neighborhood proximity). The spread of indirect effects is determined by the input’s *here factor*, *near factor*, and *far factor*, which is a simple multiplier of 0.0 to 1.0 applied to the magnitude of the indirect effect in the same neighborhood (here factor), in nearby neighborhoods (near factor) and in far-away neighborhoods (far factor). These factors are also commonly referred to as *s*, *p*, and *q*, respectively. The here factor, *s*, is 1.0 in all of the built-in rule sets, but may be set to other values by magic attitude drivers (Section 5.8). The near and far factors, *p* and *q*, are set in the model parameter database for all of the built-in rule sets; see the *Athena Rules* document for the default values, or query the model parameter database in the Athena application (Section TBD).

### Magic Attitude Drivers

The Driver Assessment Model’s rule sets cover a wide variety of events and situations, but they don’t cover everything; and in particular, they don’t cover one-of-a-kind events like the assassination of a government leader or the World Trade Center attack. *Magic Attitude Drivers* (MADs) allow the analyst to create rule sets “on the fly”. MADs can be created interactively by the analyst while the simulation is paused; alternatively, they can be created by an **EXECUTIVE** tactic. One way or another, they can affect both satisfaction and cooperation levels with both slope and level effects. See Section TBD for the mechanics.

## Politics

The Politics Area deals with actors and their strategies (goals, tactics, and attached conditions) along with the determination of support, influence, and neighborhood control. As described above in Section 2, the interplay of actor’s strategies being executed over time is the engine that makes Athena run.

### Strategies: Goals, Tactics, and Conditions

As described in Section 3.3, the actors are the significant decision makers in the playbox. Actors have *goals* that they wish to achieve, and *assets* to use to achieve them; they execute *tactics* using their assets to achieve these goals; and they decide which tactics to use, and whether or not their goals have been achieved, through the use of *conditions*.

This section will define all of these terms, and how they relate to each other. There are many different kinds of tactic, and many different kinds of condition; these are documented in the reference portion of this user’s guide, in Section TBD and Section TBD, and in the on-line help.

#### Assets

Actors can have two kinds of assets: cash, and personnel.

An actor’s personnel are simply the members of the force and organization groups owned by the actor; these groups are assigned to actors as part of scenario preparation. By executing the appropriate tactics, described in Section TBD, the actor can mobilize, demobilize, deploy, and assign activities to personnel, as described in Sections 3.5 and 3.6.

With regard to cash, each actor has two pots of money, his *cash-on-hand*, money that is available to be spent, and his *cash-reserve*, money that is being saved for use at a later time. Tactics that cost money are paid for from the *cash-on-hand*; left-over cash rolls over to the next week. The actor can use tactics to move money between his *cash-on-hand* and his *cash-reserve*.

In addition, the actor has a weekly income. In Athena 3, this income is specified as part of the scenario; in future versions, we expect it to flow to the actor from the Economic model. The income flows into his *cash-on-hand* at the beginning of strategy execution each week.

Finally, the actor can be funded by other actors. When actor A funds actor B, he does so by executing the **FUND** tactic, which transfers some quantity of A’s *cash-on-hand* to B. The money becomes available to B the following week.

#### Conditions

Actors are decision makers, and so it is necessary to allow the analyst to express in the simulation the *conditions* which lead the actors to make one decision or another. A condition is a Boolean predicate, true if some particular state of affairs exists in the simulation, and false otherwise. Athena defines a variety of types of condition; for example,

* Does actor A control neighborhood N?
* Is actor A’s *cash-reserve* greater than $1,000,000?
* Is group G’s mood less than -40.0?

The complete list is documented in Section TBD, and in the on-line help. In addition, it is possible for the analyst to define complex conditions using Boolean expressions via the **EXPR** condition.

An actor’s goals are defined in terms of conditions; and conditions can be attached to the actor’s tactics, to determine when and if the tactics will be considered for use.

#### Goals

Actors have goals they would like to achieve. In Athena, an actor can have any number of goals; each consists of a set of one or more conditions, specified by the analyst. If the conditions are all true, the goal is said to be *met*, and if any condition is false the goal is set to be *unmet*.

Goals are attached to tactics in the form of the **MET** and **UNMET** conditions. A goal can represent either a state-of-affairs that the actor would like to bring about, in which case the actor will execute specific tactics if the goal is unmet, or a state-of-affairs that the actor would like to preserve, in which case the actor will execute specific tactics if the goal is met.

#### Tactics

A *tactic* is an action that the actor can choose to take, possibly in support of one or more goals. He may deploy troops to neighborhoods, assign troops to do particular activities, set rules-of-engagement, fund essential services, support other actors, and so forth. There are many different kinds of tactic; each kind is defined in detail in Section TBD.

A tactic may have a cost in dollars, personnel, or both, depending on the tactic type and its parameters. Dollars spent on a tactic are consumed. Personnel used by a tactic are unavailable for use by other tactics during the same week. If the required assets are not available, the tactic cannot be executed.

Conditions may be attached to tactics; the tactic will only be considered for execution if all attached conditions are true. Thus, for example, a tactic can therefore be executed in support of a goal or goals by attaching the **MET** condition, or during a particular time interval by attaching the **DURING** condition.

Note that it is quite possible for an actor to take actions that are counter-productive given his stated goals. The Political model is not intended to compute optimal courses-of-action for the actors; rather, it is intended to allow the analyst to model the decision makers in the playbox, along with their limitations and prejudices, and track the consequences of the actions they actually take.

#### Strategy Execution

At the beginning of each week, every actor executes his strategy for the following week given the current state of affairs. This process is called strategy execution, and it is fairly straightforward:

* Each actor’s tactics are stored in priority order; the order is determined by the analyst when the tactics are created.
* All goals are evaluated, given the state of affairs that exists prior to the start of strategy execution.
* The actor considers each of his tactics in order from highest priority to lowest priority.
  + If any of the tactic’s conditions are false, the tactic will not be executed. This includes any goals attached via the **MET** or **UNMET** conditions.
  + If the actor has insufficient assets remaining, the tactic will not be executed.
  + Otherwise, the tactic is executed.

Note that “executing the tactic” does not mean that all of the tactic’s work is done immediately. Many tactics set up a state of affairs, which then plays out in the simulation over the following week. When the actor executes a tactic, one can think of that as the actor giving the relevant orders to his subordinates.

#### What the Actor Knows, and When He Knows It

Athena assumes that all of the actors execute their strategies simultaneously, without any collusion or comparing of notes. Thus, as the actor works through the process of executing his strategy, he knows two things:

* The state of affairs before he started.
* The decisions he has already made during the current execution process.

For example, he knows how many troops he has already deployed during the current strategy execution process.

The relevant conditions are defined according to this scheme, following the basic rule: when actor A is querying his own assets and decisions, he sees their current values as of that point in strategy execution, but when he is querying the assets of and decisions of others he sees the information as of the beginning of strategy execution.

### Support, Influence, and Control

We say that an actor “controls” a neighborhood when the residents of the neighborhood hold him responsible for dealing with the neighborhood’s problems. The actor in control is blamed when things go poorly, and praised when things go well; these things affect the vertical relationships between the residents and the actor (Section 5.3). The second significant role of the political model is to determine who is in control, and when control has shifted from one actor to another.

The basic paradigm is as follows: actors receive *support* from the people in the neighborhood (including force group personnel). An actor with sufficient support is said to have *influence* in the neighborhood. Depending on the relative influence values, the actor with the most influence is usually the one said to be “in control”.

#### Support

Group G is said to support actor A directly in neighborhood N if:

* G’s vertical relationship with A is strong enough (nominally, greater than 0.2)
* G’s security in N is high enough.[[7]](#footnote-7)

In essence, group G has to *want* to support A, and has to have sufficient freedom of movement to be *able* to support B. Support is 0 if G does not support A, and increases from there with increases in population, vertical relation , and security.

Actor A’s direct support in N is the sum of his support from all groups in N; the result is a number from 0.0 to 1.0, and can be thought of as the fraction of the neighborhood that supports A. Note that support is not a zero-sum game: group G can support any number of actors to differing degrees.

Actor A can use this support in three ways:

* Actor A can try to gain influence in N
* Actor A can support some other actor in N
* Actor A can choose not to use his support at all, thereby bowing out of the political process all together. (Actors that own organization groups often do this.)

Support received from other actors is called derived support; and actor A’s total support is simply the sum of the two. Note that because of derived support, an actor can find himself with enough influence to be in control of the neighborhood even if he gives his own direct support to another actor or to no one.

The analyst specifies, as part of the scenario, each actor’s choice of whom to support by default: himself, some other particular actor, or no one. Then, the actor may change who he supports in each neighborhood from week to week using the **SUPPORT** tactic.

#### Influence

Actors have influence in a neighborhood in proportion to their support relative to other actors. If only one actor has support in the neighborhood, only that actor can have any influence. Note that influence requires at least a minimal amount of support, nominally 0.1; this prevents a negligible force (e.g., a Red Cross team) from moving into a neighborhood that’s in a state of chaos and finding themselves in control despite having almost no support.

Influence is computed by taking the set of actors who meet the minimum support requirement, and normalizing their total support figures. Thus, an actor’s influence is a number between 0.0 and 1.0; and influence *is* a zero-sum game. An actor cannot increase his own influence without decreasing the influence of the other actors.

#### Control

As part of scenario preparation, the analyst specifies which actor is in control of each neighborhood; this includes the possibility that *no* actor is in control of the neighborhood at the start of the scenario. Then, at the end of each week Athena looks to see which actor (if any) will be in control for the following week.

Suppose that actor A is in control of neighborhood N:

* If actor A has more than the threshold amount of influence (nominally 0.5) in neighborhood N, then actor A remains in control of N.
* If A has less than the threshold amount, but more than any other actor, then A remains in control, though in a rather precarious position.
* If some actor B has more than the threshold amount of influence, then B is now in control; **control has shifted**.
* If at least one actor has more influence than A but no actor has more than the threshold amount, then no actor has control of the neighborhood; **control has shifted**.

If no actor was in control of N, the rules are simpler:

* If some actor B has more than the threshold amount of influence, then B is now in control; **control has shifted**.

To put it in another words, the actor in control must be dominated by some other actor to be seen to have lost control; but that other actor might not be powerful enough to take control himself. Control of the neighborhood is then up for grabs.

#### When Control Shifts

When control does shift to a different actor, or no actor, the civilians respond to the change:

* There is a new political situation, and a new baseline is established for computation of vertical relationships (Section 5.3)
* The change affects the attitudes of the civilian groups resident in the neighborhood; see the **CONTROL** rule set in the *Athena Rules* document.

## Economics

The Athena Economics model models the economy of the region of interest, which can be an entire country, a portion of a country, or several small countries taken together. We refer to this as the *local economy*. The core of the model is a three-sector Computable General Equilibrium (CGE) model, a system of non-linear equations solved using the Gauss-Seidel algorithm. The CGE is described in full detail in the *Athena Analyst’s Guide*; this section will give an overview, and discuss how the Economic model relates to the rest of Athena.

***Note:*** *The three-sector CGE is essentially a prototype and a proof-of-concept; while it is not without value, it is limited in its applicability. We have designed a more robust six-sector CGE, which we expect to implement in Athena 4. For this reason, Athena disables the current Economic model by default; should you wish to use it, see Section TBD for instructions.*

### Dollars

Athena represents money in “dollars”; however, no attempt is made to tie the value of an Athena “dollar” to that of a real dollar. If the inputs to the CGE are given such that Athena’s monetary units correspond to some real currency, then they do; and if not, then not.

### Sectors

The CGE partitions the local economy into three sectors: **goods**, **pop**, and **else**:

**The “goods” sector**

The **goods** sector includes all production of goods and services in the local economy. The unit of production is the *goods basket*, abbreviated “GBasket”, a notional basket of goods and services nominally costing about $1.

**The “pop” sector**

The **pop** sector includes all labor by the workers in the local region, and all consumption by the population of the local region. The unit of production is the work-year of an *average worker*. Just as the goods basket represents a notional bundle of goods and services, the average worker represents a notional bundle of skills and kinds of work.

**The “else” sector**

The **else** sector represents everything else in the local economy that isn’t covered by the first two sectors, as well as the entire rest of the world. In practice, the “rest of the world” means imports and exports. The unit of production is the *else basket*, abbreviated “EBasket”, which is similar to the goods basket and also nominally costs about $1.

Each sector produces a certain amount of output; measured in dollars, this output is called the *revenue* of the sector. In the process of producing its output, the sector consumes the output of all three sectors; measured in dollars, this vector is called the sector’s *expenses*.

### Shape vs. Size

We distinguish between the *size* of the economy, which can be roughly thought of as total revenues, and the *shape* of the economy, or the proportion of revenues across the sectors. The size of the economy is driven by consumption: increase the number of consumers, or the amount consumed by each, and the economy must increase in size. Decrease the amount of consumption, and the economy must shrink. But as the economy increases and decreases in size, its basic shape remains the same, because the basic industries and technologies in use remain the same.

The size of the economy is therefore driven by the number of consumers, which comes from the Demographic model (Section 4). The shape is determined by the following inputs:

* The base wage: the average wage for one work-year, in dollars.
* The average consumption of goods by each consumer each year, in goods baskets.
* The Cobb-Douglas parameters for the three sectors; these parameters determine the mix of inputs required to produce one unit of the sector’s output, assuming a Cobb-Douglas production function.

Setting these parameters is called *calibrating the Economic model*; the process is described in Section TBD.

In theory we should also set the base prices for the **goods** and **else** sectors, but as we have defined the goods basket and the else basket as baskets worth $1 at time 0, the base price is naturally $1.

### Economic Outputs

The Economic model is run once a week. Each week, it produces the following outputs for pair of sectors *i* and *j*.

* The quantity demanded: the number of units of sector *j*’s output purchased by sector *i*.
* The expense: the dollars spent by sector *i* to buy the quantity demanded of *j*’s output.

Then, for each sector:

* The price: the price of one unit of the sector’s output, in dollars.
* The quantity supplied: the output of the sector, in the sector’s units of production.
* The revenue: the output of the sector in dollars.
* The expense: the dollars spent on the ingredients by the sector.

And then, for the local economy as a whole:

* The unemployment rate, as a percentage of the size of the work force.
* The gross domestic product (GDP), in dollars: the total revenue of the economy, excluding the **else** sector, i.e., the “size” of the local economy.
* The consumer price index (CPI), which measures changes in buying power since the start of the simulation.
* The deflated gross domestic product (DGDP), which is simply the GDP divided by the CPI. This gives the current “size” of the local economy in “time 0” dollars.

### Neighborhood Aggregation/Disaggregation

The CGE covers the entire local economy; but Athena generally deals with happenings in particular neighborhoods. Thus, we need to aggregate neighborhood inputs for use by the CGE, and disaggregate CGE outputs down to the neighborhood level.

#### Neighborhood Aggregation

The relevant figures are the number of workers, the number of consumers, and the production capacity of each neighborhood. The Demographics model outputs the first two, as described in Section TBD. The Economic model itself determines the production capacity of each neighborhood as follows:

* The size of the economy is solved at time 0.
* The quantity supplied by the **goods** sector represents the production of the playbox at time 0.
* We allocate that quantity supplied to the neighborhoods by neighborhood labor force size, yielding the production of each neighborhood.
* We assume that each neighborhood is producing at its capacity at time 0.
* We give each neighborhood a “production capacity factor”, or PCF. A PCF of 1.0 represents the neighborhood’s production at time 0. The PCF can be increased or decreased to reflect increases or decreases in the neighborhood’s production capacity.

The total production capacity of the economy is then the sum of the production capacities of the neighborhoods; this limits the size of the economy in the same way that the size of the labor force does.

#### Neighborhood Disaggregation

It would seem reasonable to disaggregate a number of outputs to the neighborhood level, such as the total production of goods or the wages paid. This rarely turns out to be useful, however, as the only basis for doing so is usually the population size, which was used to do the aggregation to begin with.

Consequently, we currently disaggregate only the Unemployment Rate, resulting in the number of unemployed workers per neighborhood. This turns out to be interesting because the size of the labor force as a fraction of the population varies from group to group and neighborhood to neighborhood, due to the subsistence agriculture percentage (Section 4.3). We then use the number of unemployed workers relative to the neighborhood population to drive the Unemployment situation (Section 4.5).

### Ways to Affect the Economy

In Athena 3, there are four ways to affect the economy:

* Civilian casualties can decrease the number of consumers and workers.
* When displaced from their land, the subsistence population willy-nilly become consumers, and might or might not contribute to the labor force.
* When a civilian group’s security decreases, workers can stay at home out of fear, thus reducing the effective size of the labor force.[[8]](#footnote-8)
* Each neighborhood’s Production Capacity Factor can be increased or decreased, reflecting the building of new plant or destruction of existing plant, and thereby changing the economy’s production capacity.

### Effects of the Economy

There are many ways in which the economy *should* affect Athena; at present, the only implemented effect is that of unemployment on the civilian population (Section 4.5). In addition, the analyst can track the GDP and the CPI, and use them to inform his own interventions.

## Information

Information, its use, and its spread are crucial in the kinds of scenarios Athena has been designed to address. The Information Area includes the following:

* Command and control of troops and organizations
* The spread of information within the civilian population and across the playbox
* Intelligence received by force groups (and hence by actors) from the civilian population
* Information operations: propaganda and other media techniques intended to affect the perceptions of the people in the playbox, so as to:
  + Increase support for an actor
  + Decrease support for an actor
  + Skew the intel available to an actor, thus affecting the activities driven by it.

At present, Athena’s information modeling is fairly simple:

* GRAM tracks the cooperation (willingness to give information) of civilian groups with force groups; cooperation has a number of effects across the playbox, and especially on combat.
* GRAM includes a simple model of information flow across the playbox as it applies to attitude effects.

For the rest, information flow is implicit in Athena’s models. This is a major area for future work.

# Part II: Using Athena

## Installation

Athena requires 32-bit Windows, and specifically Windows 7, and is known to operates on 64-bit Windows 7. It is believed to operate on Windows Vista, and may also work on Windows XP.

To install Athena, first acquire the installation wizard from the TRADOC G-2 Intelligence Support Activity (TRISA) at Ft. Leavenworth, Kansas; at time of writing, the contact is Robert Crowson, at [Robert.Crowson@us.army.mil](mailto:Robert.Crowson@us.army.mil). Save the installer to your desktop and execute it in the usual way; the wizard will lead you through the installation process.

### Starting Athena

At the end of the process Athena will be available from the Start menu, and optionally as an icon on your desktop. In addition, you can start Athena with a particular scenario by double-clicking on the scenario file.

### Athena Documentation

The Athena documentation, including this User’s Guide, is available on the Windows Start menu. In addition, the Athena application has extensive on-line help; select any help topic from the Help menu.

### Multiple Versions of Athena

Multiple versions of Athena can coexist on one machine, and will have distinct entries on the Windows Start menu. However, there are two caveats.

Double-clicking a scenario file will always invoke the most recently installed version of Athena. This will usually be what you want. If it is not, invoke the correct version, and use its File/Open menu item to open the scenario.

Second, the scenario file’s schema frequently changes during Athena development. If you are running development builds (e.g., version 3.0.*x* or 4.0.*x*) be aware that a scenario created with one version might not work with a later version, and that you might have to take extra steps to convert it. Release builds (e.g., successive releases of version 3.1.*x* or 4.1.*x*) do not have this problem. When installing a new version, always look at the Release Notes (available with the Athena documentation on the Windows Start menu); they will tell you of any version incompatibilities.

## Using the Athena Application

This section gives a top-level overview of the Athena application and how to use it.

### Athena Scenario Files

Athena is a document-centric application, like a word processor or spreadsheet application. In Athena’s case, the documents are called *scenario files*. Each scenario file includes the data required by a single Athena scenario: neighborhoods, actors, groups, strategies, and other inputs. If saved after the Athena simulation has run forward in time, the scenario file will also include the results.

Athena provides the usual File/New, File/Open, File/Save, and File/Save As menu items; you can also invoke Athena with a specific scenario file by double-clicking the scenario file in the Windows Explorer (but see Section 9.4 if you have multiple versions of Athena installed).

By default, Athena saves scenario files in your Documents\Athena folder. However, you may save them anywhere you like.

### Athena Workflow

Athena operates in several distinct states; what you can do varies from state to state. The states are shown in the following diagram:



When you create a new scenario, Athena is in the *Scenario Preparation* state, called **Prep** for short. In this state you create the scenario, adding neighborhoods, actors, groups, strategies, and so forth. When you’ve defined the scenario to your liking, you *lock* the scenario, entering the **Paused** state. In this state the simulation is initialized, but time is not advancing. You can examine the initial state of the simulation, and then either return to the **Prep** state or tell Athena to run time forward.

While time is advancing, Athena will be in the **Running** state; in this state, most user input is blocked. After advancing time the appointed amount, Athena will return to the **Paused** state, where you can examine the results. You can then make changes, if you like,[[9]](#footnote-9) and direct Athena to continue advancing time. Alternatively, you can unlock the scenario, returning the **Prep** state (and losing any simulation results). Once there, you can revise the scenario and start over.

Finally, each time Athena leaves the **Paused** state for the **Running** state it saves a snapshot of the current state of the simulation. Whenever the simulation is **Paused** you can browse through these snapshots, examining the state of the simulation at these earlier points in simulation time. In this **Snapshot** state you cannot make any changes, but you can view all outputs. While viewing a snapshot, you can choose to return to the latest simulation time, or “re-enter the time stream” as of the snapshot time, make changes, and run forward from there. Finally, you can always unlock the simulation and return to the **Prep** state.

Note that if you save the scenario while Athena is **Paused** or in the **Snapshot** state, all simulation results and snapshots will be saved in the scenario file, and will be available when you re-open the file.

### Scenario Mode vs. Simulation Mode

In the **Prep** state you can edit the scenario, but you can’t advance simulation time. In the **Paused** state, you can advance simulation time, but you can’t edit the scenario. The data and tools required are different in these two states, and Athena’s user interface updates to match. In *Scenario Mode*, Athena displays the tools you need to create and edit the scenario. When you lock the scenario, Athena switches to *Simulation Mode*, and displays the tools you need to control simulation time and view the results.

While in Simulation Mode many of the screens used to input scenario data are not available; however, you can still find the scenario inputs using the Detail Browser (Section TBD). Alternatively you can unlock the scenario, or temporarily switch the GUI back to Scenario Mode using the View menu.

### Viewing Athena Results

Athena provides a great many tools for browsing the Athena results interactively, including a number of bar charts and line plots; these tools will be described in Section TBD. The most important of these tools is the Detail Browser, which provides a web-browser-like view of all of the scenario data.

It is also possible to access Athena results programmatically. The Athena scenario file is an SQLite database file[[10]](#footnote-10); SQLite bindings are available for most programming languages. You can browse Athena’s SQL database scheme by entering the address “my://rdb” into Athena’s Detail Browser (Section TBD).

### Athena Scripting

Athena provides significant support for scripting through the Athena *Executive*, a scripting language processor based on the Tcl programming language.[[11]](#footnote-11)

#### Executive Commands

The Athena Executive extends the Tcl programming language with a wide variety of *executive commands*; these commands can create and revise neighborhoods, actors, groups, and so forth, lock and unlock the scenario, advance time, and so forth. The complete list of executive commands is given (with full documentation) in the Athena application’s on-line help; select “Executive Commands” from the Help menu.

The most important executive command is the send command, which is used to send *orders* to Athena. See Section TBD for more about Athena orders.

#### The Athena Command Line

Executive commands can be entered interactively by the user at the Athena command line. The command line is not displayed by default; to make it available, select “Command Line” from the View menu.

#### Executive Command Scripts

The user can also place a succession of executive commands in a text file using NotePad or some other text editor; such a file is called a *script*. In addition to Athena’s executive commands, the file may contain general Tcl-language program code, including loops, conditionals, procedures, and so forth. Such a script can be called in a number of ways:

* From the Athena Command Line, using the call command.
* When invoking Athena in batch mode (see Section 10.6).
* By **EXECUTIVE** tactics (see Section TBD).

It is customary to give executive scripts a “.tcl” extension, e.g., “myscript.tcl”.

#### Scenario Scripts

Although the user interface hides this from the user to a great extent, an Athena scenario is built by sending a sequence of orders to Athena. These orders create and update neighborhoods, groups, and so on. Athena keeps track of the series of orders that leads to its current state; you can save them to disk as a script of send commands by using the export command at the Athena Command line:

> export myscenario.tcl

>

This will save the script as myscenario.tcl in the same directory as the scenario file. The script can then be executed in the usual way to recreate the existing scenario, or edited by hand to create a slightly different scenario. This provides a convenient way to load an existing scenario into a new version of Athena when using development builds (Section 9.3): export it from the old version, make any necessary changes by hand, and load it into the new version.

Naturally, scenario scripts can also be created by hand or by other software; this can be a convenient way to load data from other databases into Athena. It is simply necessary to use the proper sequence of Athena orders. See Section TBD and the application’s on-line help for documentation on the individual orders.

### Batch Mode

Athena can be invoked in *batch mode* from the Windows command line or by other programs. In batch mode Athena has no user interface; instead it initializes itself, runs a script, and then shuts down. Typically the script will advance time and save the scenario under another name. The results can then be acquired by querying the saved scenario file as an SQLite database.

#### Invoking Athena in Batch Mode

To invoke Athena in batch mode, use the following command line (question marks denote optional arguments):

athena.exe –batch –script myscript.tcl ?myscenario.adb?

In batch mode:

* No GUI is created.
* A scenario file is loaded, if one is given on the command line.
* A script is executed if the –script option is given.
* If results are to be saved, the script must explicitly call the save command.
* Athena exits.

If Athena runs with no errors, it will terminate with exit code 0. If any error occurs, details about the error will be written to the file “error.log” in the user’s working directory, and Athena will terminate with exit code 1.

#### Simulation Control

In batch mode, the simulation is controlled by a script of executive commands specified using the -script option. Documentation for the Athena executive commands is in the Athena help; to view it, invoke Athena interactively, and select Help/Executive Commands from the menu bar.

The following executive commands will be most useful; see the Help for full details, including command syntax:

* advance: Advances simulation time.
* call: Calls another script.
* export: Exports the current scenario as a script.
* load: Loads a scenario file.
* lock: Locks the scenario so that time can advance.
* new: Creates a new, empty scenario.
* save: Saves the scenario, including any simulation results.
* send: Sends an Athena order.
* unlock: Unlocks the scenario, so that basic scenario data can be changed.

#### Simulation Results

To process simulation results, use the save executive command to save a scenario file after advancing time; this file will contain the results, along with all of the other scenario data. The results can be viewed in two ways:

* First, you can open the file in Athena and browse it interactively.
* Second, the scenario file is an SQLite database; any SQLite client can open it and execute queries. You can browse the schema by running Athena interactively and entering "my://rdb" into the Detail Browser's address bar.

# Part III: Athena Cookbook

TBD

# Part IV: Reference

## Tactic Types

TBD

## Condition Types

TBD

## Glossary

TBD

## Acronyms

1. A piece-wise linear approximation to an S-curve. See the *Mars Analyst’s Guide* for details. [↑](#footnote-ref-1)
2. For the purposes of this section, both mere presence and assigned activities count as activities. [↑](#footnote-ref-2)
3. This is not realistic; displaced subsistence farmers usually lose their land and livestock, and hence cannot easily go back to subsistence agriculture. [↑](#footnote-ref-3)
4. Except, of course, in non-local neighborhoods. The number of consumers and laborers in these neighborhoods is ignored. [↑](#footnote-ref-4)
5. Cynical? Yes. Your point? [↑](#footnote-ref-5)
6. The Athena team invariably uses the term “concern”; our sponsors seem to prefer the term “soft factor”. [↑](#footnote-ref-6)
7. We use a Z-curve to convert the base security level, -100 to +100, into a multiplier ranging from 0.0 to (usually) 1.0. [↑](#footnote-ref-7)
8. This part of the model is known to have problems, which will be resolved in the six-sector model. [↑](#footnote-ref-8)
9. Note that there are many changes (e.g., adding a group) that you can only do in the **Prep** state. [↑](#footnote-ref-9)
10. See sqlite.org for more information. [↑](#footnote-ref-10)
11. See www.tcl.tk for more information. [↑](#footnote-ref-11)