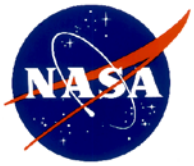
JPL Publication 13-9



Athena in 2013 and Beyond

Robert G. Chamberlain

William H. Duquette

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

May 2013

The research described here was carried out by the Athena development team at the Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA 91109-8099, and is sponsored by the U.S. Army TRADOC G2 Intelligence Support Activity and the National Aeronautics and Space Administration.

ABSTRACT

TRISA, the U.S. Army TRADOC G2 Intelligence Support Activity, received *Athena 1* in 2009. They first used *Athena 3* to support studies in 2011. This paper describes *Athena 4*, which they started using in October 2012. A final section discusses issues that are being considered for incorporation into *Athena 5* and later.

Athena's objective is to help skilled intelligence analysts anticipate the likely consequences of complex courses of action that use our country's entire power base, not just our military capabilities, for operations in troubled regions of the world. Measures of effectiveness emphasize who is in control and the effects of our actions on the attitudes and well-being of civilians. The planning horizon encompasses not weeks or months, but years.

Athena is a scalable, laptop-based simulation with weekly resolution. Up to three months of simulated time can pass between game turns that require user interaction. Athena's geographic scope is nominally a country, but can be a region within a county. Geographic resolution is "neighborhoods", which are defined by the user and may be actual neighborhoods, provinces, or anything in between. Models encompass phenomena whose effects are expected to be relevant over a medium-term planning horizon—three months to three years.

The scope and intrinsic complexity of the problem dictate a spiral development process. That is, the model is used during development and lessons learned are used to improve the model. Even more important is that while every version must consider the "big picture" at some level of detail, development priority is given to those issues that are most relevant to currently anticipated studies. For example, models of the delivery and effectiveness of information operations messaging were among the additions in *Athena 4*.

ABOUT THE AUTHORS

Robert G. Chamberlain is particularly enthused by the prospect of finding mathematical models that solve—or at least contribute to the understanding of—new problems. His search for interesting challenges has allowed him to contribute in many application areas during the half century he has been at the Jet Propulsion Laboratory, where he is now a principal. He enjoys developing new tools as much as becoming expert in the use of techniques developed by others. After thirty years of doing operations research and systems analysis on space and civil systems projects, he developed models for the Corps Battle Simulation for fourteen years, and was then instrumental in the initiation and development of the Joint Non-kinetic Effects Model. He created the master plan for the Athena model and is the chief modeler for Athena.

William H. Duquette is a software engineer with a background in mathematical modeling and operations research. In his over twenty-five years at the Jet Propulsion Library, he has worked in areas as diverse as modeling and simulation, terrain rendering, and JPL's Deep Space Network's ground system. For the past seven years, he has been the lead software developer on the Joint Non-kinetic Effects Model, followed by the Athena model, and is now the overall development lead for Athena.

TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 Requirements

Athena is intended to help skilled, well-informed intelligence analysts anticipate the medium-term consequences, intended and otherwise, of courses of action that use the elements of national power for operations in complex modern environments.

The objective of the Athena Project is to provide a single-user decision support tool that meets the following requirements:

- The tool is a simulation program that operates on a laptop computer.
- Operations must allow use of all elements of national power (DIMEFIL).
  Diplomatic, Informational, Military, Economic, Financial, Intelligence, Law Enforcement
- Operations must be evaluated in the complex contemporary environment (PMESII+PT).
  Political, Military, Economic, Social, Infrastructure, Information, Physical Environment, and Time
- The analyst must be able to follow causal chains from strategic choices to outcomes.
  Through scenario design, data, goals, tactics, events, and outcomes
- Geographic scope: sub-national to national.
  The tool should be applicable in all parts of the world
- Planning horizon for courses of action: in the range 3 months to 3 years.

Low-level, detailed requirements are poorly understood until discovered during the anticipation–development–use–feedback cycle.

1.2 Use

To use Athena, the analyst creates a simulated environment, as suggested by Figure 1. The people in this environment are the actors, civilian groups, force groups, and organization groups. The scenario defines the communications and manufacturing infrastructures of the region being studied. Initial conditions specify the state of the economy and civilian attitudes.

The analyst defines actors' strategies, then runs the simulation, interacting as desired to update actors' strategies based on what occurs in the simulation. Causality traces in the on-going and final outputs facilitate assessment and revision of the courses of action.

1.3 The Simulation

As the simulation runs, the actors execute their strategies every week by choosing tactics for the next week from their prioritized lists. As each tactic on the list is considered, Athena first determines whether the conditions attached to the tactic are met. If they are, it allocates the necessary assets (if the actor has them; if not, he won't use that tactic), then considers the next tactic on the list, and so on. The actors' tactics interact to drive what happens in the simulation.

Tactics express how the actors use their power. They can, for example, make alliances with other actors, conduct information operations, engage in military actions, provide essential services to civilian neighborhoods, and build bridges and schools. They can even save money for later use—or send it to a private bank account offshore.

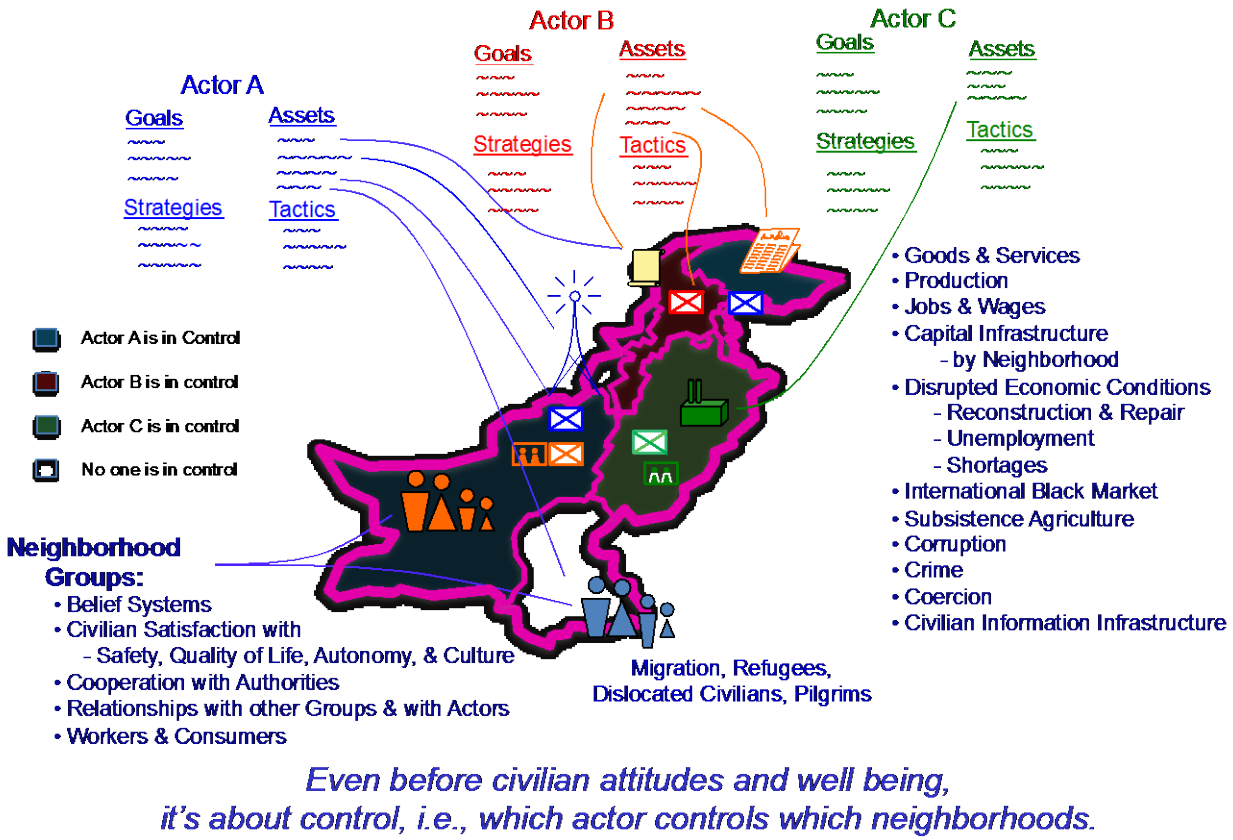


Figure 1. The Simulated Environment. Actors derive income from the economy. They use their strategies to choose tactics, but are constrained by their assets. They only consider those tactics whose conditions are met. Civilians are aggregated into neighborhood groups. Their attitudes are affected by what happens in the simulation, including information operation messaging. Support for actors depends on civilian attitudes; control of neighborhoods depends on both civilian support and force.

The conditions that can be attached to tactics are quite general. They can, for example, be timing constraints, assess whether specific goals have been achieved, and check who is in control of which neighborhoods.

The asset types tracked in *Athena 4* are funds, personnel, and access to media. Later versions of Athena may track additional types of assets.

There are three kinds of groups of people in the model. *Civilian groups* are people who share some common traits (religious, ethnic, or otherwise) and live and work in neighborhoods. *Force groups* represent military forces and come in several varieties: criminal, militia, police, paramilitary, and regular military. *Organization groups* generally provide humanitarian aid to the civilians. Civilian groups are autonomous and respond as dictated by Athena's models and rules. Force and organization groups are controlled by actors.

The attitudes of the civilian groups are described in terms of several attributes. These include their satisfaction with regard to each of four fundamental concerns, the extent to which they cooperate with each of the force groups, the relationships they have with each other, the relationships they have with each of the actors, and ultimately, the support they provide to the actors. These are all affected directly by events and situations that occur in the simulation and indirectly by what happens to their friends and enemies. The magnitudes of these effects are

estimated by a combination of common-sense algorithms and rules that were vetted and calibrated by subject matter experts.

The state of the economy depends on the production capacity, aggregated over the neighborhoods, on foreign aid and remittances, and on whether people are afraid to shop or to go to work. Both the supply of labor and the demand for goods can be affected by movements of refugees and pilgrims. Unemployment can have a feedback effect: less income implies less spending, less spending implies fewer jobs. Unemployment also affects attitudes.

Attitudes are also affected by economic conditions and any information operations messaging tactics that have been executed by actors.

Who is in control of a neighborhood depends on a combination of the force each actor can apply and the support he can get from civilians and from other actors.

Athena contains many specific models, which can be grouped into modeling areas. The grouping we use is for our own convenience, and boundaries between the areas are rather fuzzy. In fact, it is tempting to start a description of each of the areas with "This modeling area ties the entire Athena model together." Figure 2 shows our grouping, with Politics at the top, Information in the middle, and Ground, Demographics, Economics, and Attitudes completing the pentagram.

Figure 2. The Six Athena Modeling Areas. The *Ground* area is what's happening, where, and when. *Politics* is the actors, what they do, and who has power. *Demographics* keeps track of the civilians. The *Attitudes* area is responsible for the soft factors of how the civilians feel about things, including their relationships with each other and with the actors. The *Economics* area deals with how the GDP, the unemployment rate, and actors' incomes respond to changes in population, security, production infrastructure, taxes, and international inputs. Finally, the *Information* area deals with perceptions, especially the effect of information operations on attitudes and politics.

2.0 SOCIO-CULTURAL MODELING ELEMENTS

It is very challenging to construct computable models of socio-cultural phenomena. Many are most comfortably described in strictly narrative terms. A civilian neighborhood group's demeanor, for example, is characterized in Athena by the values *Aggressive*, *Average*, or *Apathetic*. Rules that require an assessment of their propensity to violent behavior depend on which value of this variable is associated with the group.

Many phenomena can be assigned numerical values for computational purposes, but associated narrative values provide meaning. Cooperation, for example, can be thought of as the probability that a member of a civilian group will give useful information to a member of a force group when asked. Athena uses a non-linear 7-point scale, with values ranging from *Always Cooperative* (99.9%–100.0%) through *Marginally Cooperative* (40%–60%) to *Never Cooperative* (0%–1%). The number is used when computing casualties in urban combat, but the narrative value is used when interfacing between the analyst and the model to dispel the illusion of precision that the numerical value might engender. (But if the analyst would rather use the numbers, he has that option.)

The civilian groups' satisfaction levels with respect to four fundamental concerns are a major factor in assessing their states of mind. Satisfaction is not a "utility" measure; zero is a very meaningful value. A numerical range of –100 to +100 is used and narrative values are associated with five sub-ranges. Limits are approached only asymptotically. The rules that estimate changes assume that people respond to stimuli that affect their satisfaction levels like they do to light and noise stimuli: logarithmically, but that the response is a percentage of the distance to the asymptote, as suggested by Figure 3.

Relationships between groups are also measured on a scale of –100 to +100, with the value expressing how much satisfaction one group gets out of the other group's changes in satisfaction. Negative values suggest that the groups are enemies. Relationships are not necessarily symmetrical. Relationship values are used in many rules to determine the indirect effects of things that happen in the simulation. The subject matter experts whose expertise is embodied by the rules often chose to express a non-linear relationship between effects and relationships. Their choices were made qualitatively from the options shown in Figure 4.

Many relationships between an independent variable on the x-axis and a dependent variable on the y-axis are well-described by an S-curve, with the dependent variable asymptotic to low and high values. But the S-curve itself would only provide an approximation to the real relationship, so it

Scale for Satisfaction Changes, % or %/day — of what's left to ±100

XXXXL	XXXL	XXL	XL	L	M	S	XS	XXS	XXXS
30	20	15	10	7.5	5	3	2	1.5	1

Figure 3. Scale for Satisfaction Changes. The rules use the narrative values and apply the change to the distance between the current level and the asymptote. Many rules use asymptotes other than ±100.

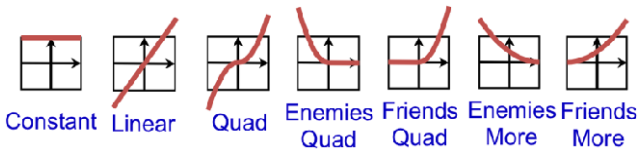


Figure 4. Relationship Multiplier Functions. The abscissa (x-axis) on these graphs is the relationship between the group experiencing the effect indirectly and the group affected directly. The relationship ranges from –1 (pathologically bitter enemies) to +1 (bosom buddies). The practical range is roughly ±0.6, but groups have a +1 with themselves. The ordinate (y-axis) is a multiplier that ranges from –1 to +1 or more. The values are scaled so the absolute values of the multipliers are 1.0 when the relationships are ±0.6.

should be drawn with a broad pen, much as the red lines in Figure 4 are drawn. Therefore, to avoid an unrealistic appearance of non-existent precision, broad-brush "Z-curves" are used, as illustrated in Figure 5. This modeling decision makes it easier for subject matter experts to specify the parameters, as they do not have to agonize over unrealistic details. The simplicity also speeds up computation.

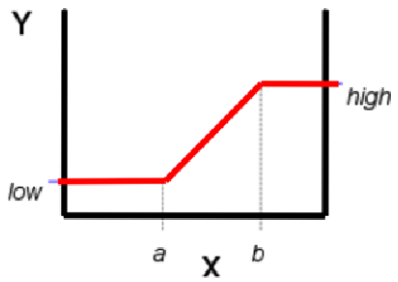


Figure 5. Generic Z-Curve. Using this simplification of an S-curve is justified by the fact that the numerical computations are far more precise than our understanding of the underlying phenomena and the accuracy of the associated data can justify. That is, a Z-curve can describe inaccurately known phenomena just as *accurately* as a deceptively more precise S-curve would.

3.0 POLITICS

Politics is about control, and the politics area is about how the actors in the region use their assets, tactics, and strategies to achieve influence and, ultimately, control. 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.

3.1 Goals, Strategies, and Tactics

The actors' strategies drive the simulation. These strategies are modeled as a prioritized list of tactics, which will be executed if their conditions are met and there are sufficient assets left after allocations have been made to higher-priority tactics. Assets currently tracked are personnel, broadcast communications assets, and cash.

Tactics are actions that an 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. Activities might involve such things as enforcing curfews, establishing checkpoints, patrolling the streets, distributing food and water, building schools and bridges, providing medical care to civilians, hunting terrorists, or ambushing government troops.

An actor's tactics can be conditioned on whether a goal is met or not. However, it is quite possible for an actor to use tactics that are counter-productive to his goals. Athena makes no attempt to compute optimal courses of action for the actors; rather, it is intended to allow the analyst to model the decision makers of the real world, along with their limitations and prejudices, and track the consequences of the actions they might actually take.

3.2 Support, Influence, and Control

An actor gains control of a neighborhood when he has enough influence to dominate the neighborhood. Influence is derived from the support of the people in the neighborhood, and depends on both the strength of their support and whether they have enough freedom of action to be able to provide support. An actor's militia or other forces support their owning actor very strongly, provide security for themselves, and can suppress those who do not support their owner. An actor that depends primarily on force for dominance must continue to do so unless he wins over the civilians.

An actor will lose control if some other actor gets more influence than he has, but he'll still be considered to be "in control" unless the more influential actor gets *enough* influence to be dominant—by default, 50% or more.

The actor in control—if there is one—is held responsible for dealing with the neighborhood's problems. He is blamed when things go poorly, and given credit when things go well. Blame and credit affect the residents' support.

Actors can share their support with other actors, forming *de facto* coalitions if the analyst gives them coordinated strategies.

4.0 ATTITUDES

How the simulated civilians feel about the current situation and how it is changing is a fundamental theme. Not only do their attitudes drive their behavior, but they are important measures of effectiveness of proposed courses of action.

Specifically, Athena addresses and tracks civilian satisfaction with respect to four basic concerns, to their cooperation with force groups, to their relationships with each other, and to their relationships with the actors. Many of these attitudes are based on the civilians' beliefs, which are also modeled.

An extensive set of rules has been developed in coordination with subject matter experts to assess the implications of events and situations. These rules produce changes in attitude variables in the model.

4.1 Belief Systems and Affinities

Every civilian group and actor has a *belief system*, consisting 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. What an actor truly believes drives the tactics he chooses to use.

To facilitate comparison of belief systems, an appropriate set of topics is identified by the analyst during scenario preparation. A belief is described by two values, the entity's *position* for or against the topic of interest 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. An extreme emphasis on disagreement on even one topic can cause a very low affinity value.

The *Affinity* between two entities is computed by a somewhat complicated formula that compares their positions on each of the topics, taking into account how strongly they feel about those who agree (or not), and normalizes the result to the range –1 to +1.

People who live in a region tend to share many common beliefs. In the model, these shared beliefs are implicit. The analyst can control how many such common beliefs there are and how closely each entity shares them; foreign actors (such as the US or UN) are generally assigned a very small commonality fraction.

4.2 Satisfaction

Every civilian group has a sense of satisfaction or dissatisfaction with the state of affairs. Satisfaction in this sense is not a feeling, *per se*, though we often use the language of feelings and talk 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 tracked in terms of four basic concerns, as indicated in Figure 6. Some concerns are more important than others, but the relative importance may vary considerably from

group to group. Thus, it is often more relevant to consider a saliency-weighted composite, which Athena calls the *mood* of the group.

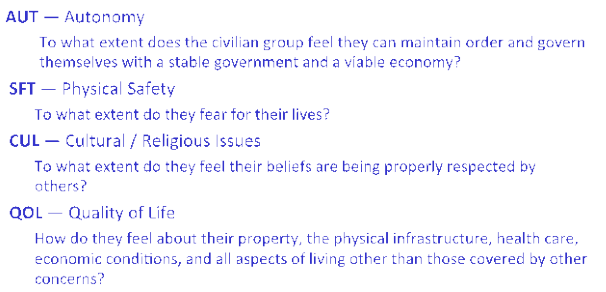


Figure 6. Civilian Concerns. These concerns are the dimensions by which satisfaction is measured in Athena. A composite, weighted by the relative importance of the concern to the group is called "mood".

4.3 Cooperation

The extent to which a civilian group cooperates with a force group is currently used only to modify the collateral damage and attrition rates in conflicts between uniformed and non-uniformed forces (i.e., insurgents).

The rules that generate changes in cooperation between a civilian group and a force group often take into account whether the force group is perceived as being responsible for the event. In *Athena 4*, reality is perceived, but the potential to model information operations designed to spin the perceptions is there.

4.4 Horizontal Relationships

Horizontal relationships describe how groups feel about each other. Originally, they were used only to assess the indirect effect that a satisfaction change in one group had on another. Thus, if something bad happening to group A would make group B feel good, a negative value was used and they could easily be interpreted as enemies. This is still their primary function, but they have proven to be useful in many other contexts as well. Note that symmetry is not only not required, but not particularly likely due to differences in the emphases put on disagreements.

Horizontal relationships between two groups are based on their affinities, but they can be changed by information operations (specifically, messaging).

4.5 Vertical Relationships

The vertical relationship of a civilian group toward an actor describes how they feel about the actor; these are the basis for the actor's support and influence. The value is initially based on the affinity between the group's belief system and the actor's publicly stated beliefs, but changes in response to whether the group blames or credits him for what happens.

Force and organization groups are modeled as being owned by actors, and their vertical relationships to their owners are assumed to be perfect (1.0). Their vertical relationships with any other actors are nominally their owners' affinities for those actors.

4.6 Attitude Spreading

As mentioned above, things that cause changes in group A's satisfaction in a particular neighborhood also affect the other groups in that neighborhood. Thus, for example, if group A takes some casualties, their friends will mourn with them and their enemies will cheer. The effect on group A is a direct effect, the other effects are indirect.

Indirect effects are not limited to the neighborhood in which the event occurred. The spread of indirect effects diminishes with distance, but physical distance is not the appropriate measure of distance. Rather, during scenario preparation, each pair of neighborhoods is categorized as being *near* or *far*, and attenuation factors are specified in the rules. To allow for

large neighborhoods, a *here factor* is also specified for use within the directly affected neighborhood. The *near* and *far* designations are not, of course, necessarily symmetrical.

Since cooperation is pairwise, the computation is more complicated, but the concept is the same.

Horizontal and vertical relationship inputs do not have indirect effects in *Athena 4*.

4.7 Trends

An attitude differs from a baseline value in response to transient stimuli. When those stimuli go away, the attitude can be expected to drop back to the baseline. However, the baseline itself tends to drift slowly toward the current value of the attitude, so continuing stimuli can be expected to have a somewhat reduced lasting effect.

The baseline is also pulled toward a natural value if one has been identified. A group's satisfaction with respect to its physical safety, for example, can reasonably be expected to drift toward some function of its security, which is modeled more or less objectively in terms of the proximity and number of their friends and enemies. As the group's security increases and decreases, so should that natural value.

Athena 4 uses a modified exponential smoothing algorithm to combine the effects of these two forces on the baseline. These trends may reinforce each other or conflict. Some "persistent" stimuli, such as the bombing of the Golden Mosque or the destruction of the Twin Towers, can be expected to change the baseline itself, directly and immediately. After these changes have been applied, the baseline again drifts toward the current value and toward the natural value.

People's capacity to respond to events and situations, their ability to feel horror and dismay on the one hand or joy and exultation on the other, can be saturated. Consequently, the attitude measures have upper and lower limits, and changes are generally applied as fractions of the difference between the current level and the limit.

4.8 Causal Tracking

Athena tracks the events, situations, and actions that lead to changes in attitudes.

5.0 ECONOMICS

The economics area determines how much funding is available to the regional actors, how many people are out of work, and whether there are shortages of goods. The overall health of the economy is reflected in the gross domestic product (GDP) and the GDP *per capita*.

Most of the economic analysis is contained in a computable general equilibrium (CGE) model, but the demographics area keeps track of the number of consumers and the size of the labor force, the ground model tracks production capacity, and actors receive taxes and tax-like revenues and decide how they are going to spend those revenues. Unemployment and shortages affect people's attitudes. Low physical security can keep people from going to work or shopping.

Because the CGE paradigm has been modified to operate within a simulation of an economy that is not in equilibrium, supply does not always equal demand and can vary from week to week.

In *Athena 4*, the economy is described in terms of six aggregated sectors: legal goods, illegal goods, the populace, actors, the rest of the region, and the rest of the world. The populace supplies labor and consumers. The other factors of production, such as capital and land, determine production constraints and can be changed—over time—by actors' decisions.

A complete description of Athena's CGE is given in (Chamberlain, Duquette, and Kahovec, 2012).

6.0 INFORMATION

Information is arguably more important than reality, because people and actors act on their *perceptions* of reality, not on reality itself. So far, the information area encompasses the spread of information within the civilian population as described above, the effect of intelligence gathering on attrition and collateral damage in encounters between uniformed and ununiformed forces, and information operations. The first kind of information operation modeled in Athena is broadcast messaging.

6.1 Broadcast Messaging

Broadcast messages are potentially a very powerful way to change people's attitudes. However, success requires that the message reaches the target audience and that it resonates with their beliefs.

Actors can send *information operations messages* (IOMs). The IOM tactic specifies which media to use; the model determines which civilian groups are within the media's coverage areas and to what extent each group pays attention to messages from that newspaper, television station, website, or whatever. If the message allows the group to determine who sponsored the message, that may also affect the penetration, depending upon how much the group trusts the perceived sender.

While setting up the actors' strategies, the analyst describes the content of the IOM in terms of a collection of beliefs (called a *semantic hook*) and a *payload*. (This must be done by the analyst because parsing of actual messages is way beyond Athena's capabilities.) The resonance between the semantic hook and each group's beliefs is approximated by the same kind of affinity calculation as is done to compute relationships between groups.

The payload is the changes in attitudes that the analyst expects the IOM would have if everything went perfectly. These are modified by the resonance and the penetration to compute the attitude changes in Athena.

7.0 DEMOGRAPHICS

The demographics area keeps track of the people: how many there are, where they are, with whom they associate, and so forth. It determines the size of the labor force, the number of consumers, the extent of subsistence agriculture, and tracks the locations and origins of displaced persons.

It also determines the effects of certain kinds of situations, such as unemployment.

8.0 GROUND

The ground area deals with the physical phenomena. It controls the flow of time and produces map displays of what is happening in the simulation. It keeps track of who are where, what they are doing, and the results of their actions. It knows about neighborhoods, combat, security, events, and environmental situations. It knows where production capacity is located and what services are being provided. Actors base their decisions on the state of affairs in the neighborhoods.

8.1 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.

Each group in a neighborhood can project a certain amount of force, depending upon what kind of group it is: Force groups, for example, exist to project force, and do so much more effectively than civilians.

But groups do not stand alone—they may have friends in the same neighborhood or nearby. Of course, that applies to a group's enemies, as well.

The *volatility* of a neighborhood is a measure of how dangerous it is to a random passerby due the general level of mutual hostility. It includes the effects of background criminal activity, which can be suppressed by law enforcement.

Danger to a group comes from its enemies, as mitigated by its friends, and from the kind of random violence measured by the neighborhood's volatility. A group's *security* is a measure of this danger.

Adding a military force to the neighborhood can increase or decrease these measures, depending upon the relationships between the force personnel and the civilians. When the actor who owns the force wants to, he can tell the force to act as if it had a good relationship with everybody; how well that works depends upon the force's training level.

8.2 Situations

Force activities, such as distributing food, building a school, or enforcing a curfew, or environmental conditions such as food shortages, epidemics, or power outages, can cause on-going situations to occur. The effects of these situations are evaluated by an extensive set of expert system rules. Environmental situations can often be mitigated by force activities.

8.3 Armed Conflict

Athena was designed to support stability and recovery operations. Thus, Athena does not model full 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 and collateral damage to civilians, with consequent effects on civilian attitudes. Outcomes depend heavily on relative cooperation levels, which reflect the effectiveness of intel.

8.4 Essential Services

An essential service is something provided to the civilians (possibly by their own efforts, as enabled or supported by actors) that they see as critical to their well-being and that has a level that can increase or decrease over time. Examples are electrical power, 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).

Satisfaction levels are obviously affected, but so are vertical relationships: Being seen as being in control of the neighborhood carries with it some responsibility. An actor who is seen as being in control will be blamed for bad levels of essential services.

The actual level of service available to each group may depend on funding by actors. To estimate effects, this level is compared to three benchmarks: the required level, the expected level, and the saturation level. Service levels below the required level lead to significant hardship. The expected level drifts toward the actual level as people get used to what they are getting. Once the civilians have all they want, the saturation level, they don't care if more is available.

Four cases are of particular interest: service is less than required or at least as much as required; if the latter, service is less than expected, it more or less meets expectations, or it is better than expected.

In *Athena 4*, only those services that do not require infrastructure are modeled explicitly.

9.0 *ATHENA 4* IN A NUTSHELL

Athena simulates the actions and responses of groups of civilians, forces, and organizations in a country in which we are engaged in or considering becoming engaged in stability and recovery operations. The civilians are aggregated into neighborhood groups, and special attention is paid to their attitudes, which include satisfaction with their fundamental concerns, peer relationships with other neighborhood groups, and support relationships with respect to the country's actors. Force groups are controlled by local and international actors. Organizations have their own agendas. Description of these groups and their initial relationships is part of the scenario design.

Actors affect how things change in the simulation. They have strategies consisting of a prioritized list of tactics. Each week, each actor executes tactics in priority order, provided the tactic's conditions are met and the actor still has sufficient assets. Asset types include personnel, money, and communications capability. Conditions can include whether his goals are satisfied, whether he is in control of a neighborhood, and many other criteria.

As things happen in the simulation, unemployment, shortages, situations, and civilian attitudes change. Actors get credit or blame for many of the things that change attitudes. This can affect the support they get from the civilians. Changes in support can lead to changes in who is in control in the affected neighborhoods.

The US actor's strategy is the course of action being studied. But it must be evaluated in the context of all the other actors' strategies as well. Maintenance of causal linkages is required to allow the analyst to develop improved, nuanced strategies and to explore branches and sequels.

10.0 *ATHENA 5* AND BEYOND

Issues that will be addressed in future versions will include some of the following, with those that are more likely to be implemented sooner earlier on the list:

Production capacity and other infrastructure control the region's ability to supply essential services, as well as consumer goods. Embodying the capital factor of production, it is the destination for most investments. Infrastructure is also a target for insurgents.

Poverty can be assessed by using the Gini coefficient with the average wage to calibrate a model of income distribution. Disaggregation of income and unemployment by neighborhood will be required for full understanding and proper assessment.

Inflation affects prices before it affects wages. It causes money from foreign sources, including remittances, to increase in value. Stocks of money—savings, bonds, debts, loans—decrease in value. Inflation and unemployment are related, and a Central Bank actor is needed because it has some special tactics that can affect both.

Investment models will require an Investment Banking sector and are critical to modeling the *economic growth and/or decline* of neighborhoods and, hence, the region.

More sectors in the CGE are needed to support the infrastructure and inflation models and to differentiate between impacts on upper, middle, and lower socio-economic classes.

Grey markets, consisting of legal goods offered over unauthorized distribution channels, are a consequence of shortages and will complicate the CGE.

Insurgency recruitment and defection may be more important than insurgency attrition. Models of rates will consider unemployment rates, wages, intergroup hostility, and many other factors.

Extending the planning horizon will require reconsideration of phenomena such as education and technological progress that have been intentionally omitted on the ground that their effects would not be realized within the current horizon.

Other important issues include *stability*, *corruption*, *coercion*, *uncertainty*, and *economic growth.*

Some issues are likely to be beyond the reach of the Athena model as presently envisioned:

Worldwide scope and *very long planning horizons* will require a different modeling paradigm.

Uncertainty bands about the outcomes of alternative decisions could be offered, but the effects of truly unpredictable events—sometimes called *Black Swans* (Taleb, 2007)—are likely to cause such uncertainty bands to be dangerously misleading.

Validation of the entire model is not feasible in the near future. The phenomena modeled are too poorly understood and too strongly interconnected. Even with the modest goal of merely "anticipating likely consequences", the best that can be hoped for is establishment of *credibility*.

Finally, if there were no customer who has courses of action to be considered, the development would have no focus. Without focus, it would be impossible to judge whether any particular issue is modeled in sufficient detail and with sufficient accuracy to produce meaningful, credible results.

11.0 REFERENCES

Chamberlain, R.G., Duquette, W.H., and Kahovec, B.J. (2012). *Athena's Computable General Equilibrium Model*, *JPL Publication 12-18*, Jet Propulsion Laboratory, Pasadena, California. 17 December 2012.

Taleb, Nassim. *The black swan: the impact of the highly improbable*, First Edition, New York: Random House, 2007.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
06-05-2013	JPL Publication	

4. TITLE AND SUBTITLE
Athena in 2013 and Beyond

5a. CONTRACT NUMBER
NAS7-03001

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Chamberlain, Robert G., and William H. Duquette

5d. PROJECT NUMBER
104058

5e. TASK NUMBER
1.1

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Jet Propulsion Laboratory
California Institute of Technology
4800 Oak Grove Drive
Pasadena, CA 91009

8. PERFORMING ORGANIZATION REPORT NUMBER
JPL Publication 13-9

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
Washington, DC 20546-0001

10. SPONSORING/MONITOR'S ACRONYM(S)

11. SPONSORING/MONITORING REPORT NUMBER

12. DISTRIBUTION/AVAILABILITY STATEMENT
Unclassified—Unlimited

Subject Category 80 Social and Information Sciences (General)

Availability: NASA CASI (301) 621-0390 Distribution: Nonstandard

13. SUPPLEMENTARY NOTES

14. ABSTRACT

TRISA, the U.S. Army TRADOC G2 Intelligence Support Activity, received Athena 1 in 2009. They first used Athena 3 to support studies in 2011. This paper describes Athena 4, which they started using in October 2012. A final section discusses issues that are being considered for incorporation into Athena 5 and later.

Athena's objective is to help skilled intelligence analysts anticipate the likely consequences of complex courses of action that use our country's entire power base, not just our military capabilities, for operations in troubled regions of the world. Measures of effectiveness emphasize who is in control and the effects of our actions on the attitudes and well-being of civilians. The planning horizon encompasses not weeks or months, but years.

Athena is a scalable, laptop-based simulation with weekly resolution. Up to three months of simulated time can pass between game turns that require user interaction. Athena's geographic scope is nominally a country, but can be a region within a county. Geographic resolution is "neighborhoods", which are defined by the user and may be actual neighborhoods, provinces, or anything in between. Models encompass phenomena whose effects are expected to be relevant over a medium-term planning horizon—three months to three years.

The scope and intrinsic complexity of the problem dictate a spiral development process. That is, the model is used during development and lessons learned are used to improve the model. Even more important is that while every version must consider the "big picture" at some level of detail, development priority is given to those issues that are most relevant to currently anticipated studies. For example, models of the delivery and effectiveness of information operations messaging were among the additions in Athena 4.

15. SUBJECT TERMS
economics, group behavior, human behavior, mathematical modeling (systems analysis), operations research, Athena Project, computable general equilibrium models, politics, demographics, information operations, simulation