

## **Continuous Validation Framework: A Case Study of SEAS and Afghanistan**

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### **ABSTRACT**

An agent-based simulation, called the Synthetic Environments for Analysis and Simulation (SEAS), has been used to provide detailed analytical support to a theater-level command to improve operational level decision making in regards to the Political, Military, Economic, Social, Informational, and Infrastructure (PMESII) dimensions of operations. SEAS allows observations from multiple perspectives, which highlights the economic, political and cultural factors that influence military and non-military PMESII outcomes.

One of the goals in support to the theater was to continuously track the current political, economic and cultural climate of the observed world by keeping SEAS data within thirty days of the current real-world date. In order to accomplish this, Simulex, Inc., the developer of SEAS, has developed and implemented a process of continuous validation under which a "Reference World" is tracked within thirty days of the current date by extracting data from multiple heterogeneous sources on a daily basis, injecting real-world events into SEAS over the recent timeline, and using referent data sources to provide assessments of the SEAS outputs.

This paper describes how the validation was conducted and how challenges were encountered/resolved, as well as the shortcomings of the effort. It is the intention that insights gained in this effort can serve to enhance future evolutions of SEAS as well as make contributions to the art and science of ABM validation.

**Keywords:** Validation, Comprehensive Approach, SEAS, Reference World

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### **INTRODUCTION**

The Synthetic Environment for Analysis and Simulation-Virtual International Systems (SEAS-VIS) has been used as a decision analytical support tool at the theater level to improve operational level decision making in regards to the Political, Military, Economic, Societal, Information, and Infrastructure (PMESII) aspects of kinetic and non-kinetic operations. Deployed at Joint Forces Laboratory for the NATO-led International Security Assistance Forces (ISAF) in early March 2007, SEAS-VIS was specifically used to support ISAF in Afghanistan in their effects based approach to operations. One of the goals in support to the theater was to continuously track the current political, economic and cultural climate of the observed world by keeping SEAS data within thirty days of the current real-world date. In order to accomplish this, Simulex developed and implemented a process of continuous validation under which the “Reference World” was tracked within thirty days of the current date by extracting data from multiple heterogeneous sources on a daily basis, injecting real-world events into SEAS over the recent timeline, and using referent data sources to provide assessments of SEAS outputs.

In this paper we present a description of the SEAS continuous validation effort at both the micro and macro levels — highlighting the processes involved, the challenges encountered and resolved, the shortcomings of the effort and the lessons learned, with the intent that insights gained in this effort can help enhance future evolutions of SEAS, as well as improve the art and science of ABM validation. We will first present a quick overview of SEAS-VIS followed by a description of the key aspects of the continuous validation effort, such as the initial configuration and validation of the reference world; the configuration and validation of the Diplomatic, Informational, Military and Economic (DIME) events that were injected into the virtual environment forward; and the validation of synthetic data with real-world data.

### **OVERVIEW OF SEAS-VIS**

SEAS-VIS is a synthetic mirror of the real world that is continuously calibrated using real-world information, such as real-time injection of major events, as well as information from public opinion polls, demographic statistics, economic reports, and academic studies of political, economic and social systems. Configurable sets of models make up SEAS. These models encompass the behavior of individuals, organizations, institutions, infrastructures and geographies while simultaneously capturing the trends emerging from the interaction among entities as well as between entities and the environment. The multi-granularity detail provides a means for inserting new models of different temporal and spatial scales, or for incorporating user-supplied data at varying levels of granularity, thereby continuously enriching and refining as new information becomes available.

### **OVERVIEW OF DATA REFRESH REQUIREMENTS**

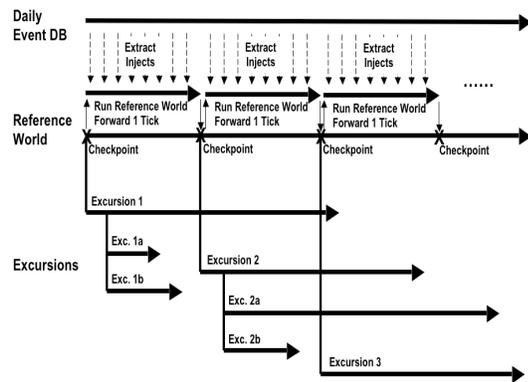
The operational theater is a dynamic environment that relies heavily on information to facilitate situational awareness and decision support. Strict requirements are placed on the currency of data as strategic, operational, and tactical decisions are made on a continuous basis in a rapidly changing environment. In the case of SEAS, the theater cell required that its data not be more than one month behind the current date, which required the development of a continuous refresh architecture such that monthly data updates could be sent to the theater based on the most current research available. With this capability, situational awareness and projections from SEAS could be relied upon more heavily on the assumption, of course, that the validation of the SEAS environment was conducted properly and the outcomes deemed reasonable.

Classification of data was a significant issue to be resolved in the continuous data refresh architecture. The theater cell not only required the availability of the best available unclassified data, but also the inclusion

of classified information as well from daily situational reports from ground personnel in the theater. With this additional requirement, Simulex developed a process under which unclassified data could be augmented with classified data (or overridden in the case where the classified data was deemed more authoritative), so the theater cell had the capability to enhance the data set with specific classified data. (It is worth noting that the theater did not have the resources to fully maintain the data themselves, so data services were provided by Simulex, which operated in an unclassified environment).

### SEAS VALIDATION PROCESS

The SEAS continuous validation effort essentially consisted of a two tier process: a) validation of the initial configuration of Afghanistan, and b) continuous validation of SEAS-Afghanistan, with data updated, refreshed, calibrated and validated within one month of the current date. Once these steps were completed (with step b occurring iteratively), various courses of action were submitted, evaluated and refined as necessary (see below).



The first stage consisted of the configuration and validation of provincial-level data, which included demographic data (traits such as ethnicity, religion, sect, tribe and sub-tribe, well-being and attitude), data on key leaders and organizations (types and attitudes), and data on information and infrastructure nodes (capacity). An important aspect of the configured data set was the attitudes of leaders and organizations toward key chosen entities. Five significant sides were chosen as “Human-in-the-Loop” (HITL) players:

- Government of USA
- Government of Afghanistan
- ISAF
- Taliban (Afghanistan)

- Al Qaeda (Afghanistan)

This stage also consisted of validating aggregate emergent statistics at the provincial level.

The second stage focused on continuous validation, specifically tracking changes in Afghanistan in SEAS VIS from its initial configuration in March 2007 and comparing it with actual data, while attempting to ensure that simulation output and real-world data were separated by no more than 30 days. Significant DIME events were injected weekly along the simulation timeline, and the resulting simulation outputs were evaluated against reported field/third party data.

Validating system outputs also required that we validate system inputs. While inconsistencies between synthetic and real-world data may be due to the calibration of various models, it may also be due to a reliance on a non-representative set of DIME inputs across all HITL players used to run the system forward. Thus, validating the set of DIME actions injected into the system was also a critical aspect of the continuous validation process.

Tracking Afghanistan had some inherent challenges, such as the paucity of data on Afghanistan as well as inconsistencies in the format of the data that was available. Nonetheless, available field data was used to configure and validate data in both stages of the continuous validation process. We begin with a description of the first stage of this process: the initial configuration of the reference world.

### CREATING THE “REFERENCE WORLD” STARTING POINT

Creating “virtual” Afghanistan’s initial conditions required representing and validating economic, political, and demographic data for Afghanistan as well as the initial emergent statistics. The goal was to provide a valid explanation for SEAS parameters and outputs based on the best-known field/third party data and subject matter expert (SME) conclusions.

We collected data at the national, provincial (34) and district (398) levels for all PMESII categories that were then mapped to SEAS IOIIG (Individual, Organization, Information, Infrastructure and Geography) categories. The type of data that was collected and verified consisted of economic data (GDP, production, sector output, etc.), demographic data (population, ethnicity, religion, tribe/sub-tribe, income class, etc.), political data (national and provincial government ministers and officials, insurgent groups and leaders, strength of government institutions, etc.), public opinion data

(public attitudes towards central and provincial government, Taliban, USA, etc.), and information on key organizations and infrastructure nodes (public and private organizations, Kajaki dam in Helmand province, etc.).

Gathering and verifying all of this data to initially configure the reference world at different granularities was the critical first step, which essentially required the successful completion of three main tasks: (1) identifying and documenting relevant sources of data and information; (2) developing a parameterization methodology to configure the traits and parameters of SEAS agents; (3) and the validation of the initial emergent data. It should be noted that the amount of data that was initially collected and configured numbered in the thousands, and therefore we were not able to validate every data point produced by SEAS to initially configure the reference world. Thus, our validation efforts in this stage were focused on validating provincial profiles for each of Afghanistan's 34 provinces.

The first step in creating the initial configuration of the reference world was identifying and qualifying useful sources of data and information. Given its status as a very poor country, Afghanistan has limited capacity and resources to gather, synthesize and disseminate data. As a result, we relied upon a number of sources to populate the initial configuration of the reference world. Key sources included the World Bank, the International Monetary Fund, the CIA World Factbook, Afghan government agencies such as the Central Statistics Office, academic studies, as well as reports and data produced by think tanks and research units, such as the International Crisis Group, the Center for Strategic and International Studies (CSIS), and the Afghanistan Information Management Service.

We also relied on public opinion surveys sponsored by organizations such as the Asia Foundation, Charney Research, the Environics Research Group and the Senlis Council. These surveys provided data on Afghan attitudes regarding the central and provincial governments, the U.S., NATO, the Taliban and Al-Qaeda at a specific point in time, and they proved to be immensely valuable. Unfortunately, surveys of Afghan attitudes occur relatively infrequently, and we usually had to work with only one or two data points per year.

The next step in creating the reference world involved the development of a parameterization methodology to populate the traits and parameters of the various agents within SEAS. There were two key aspects in regards to this step. First, we had to translate existing field data into SEAS formats. Key parameters such as

public opinion towards various entities, and citizen well-being, are populated on a 0 – 7 scale in SEAS, with higher numbers representing greater satisfaction or approval. Most field data, however, exists in a different format. For instance, public opinion surveys measuring public attitudes towards the national government typically report the percentage of those surveyed that either support or disapprove of the way the government is governing. These percentages had to be converted to a 0 – 7 scale.

Other examples of mapping survey results into SEAS were less straightforward, making it necessary to develop explicit ranking methodologies that mapped survey data to a 0 – 7 scale. For instance, the National Risk and Vulnerability Assessment (NRVA) is a report published by the Afghan Ministry of Rural Rehabilitation and Development (in conjunction with various international agencies) that contains a plethora of demographic and socioeconomic data on Afghanistan at the provincial level. Table 4.8.2 of the 2003 report provides information regarding the availability of public transportation in each province.<sup>1</sup> Pollsters questioned Afghans regarding the amount of travel time required to reach public transportation, with responses ranging from “In the community” and “Less than ¼ day” to “1/2 to 1 day” and “More than 1 day”. Freedom of Movement needs in SEAS was populated based upon the reported distribution of a province's population across these categories. Specifically, the higher the percentage of a province's population that had to travel a longer distance to access public transportation, the lower the parameterization for the Freedom of Movement needs fulfilled for the agents representing citizens in that province. Thus, one of the challenges that had to be overcome in configuring the initial instance of the reference world was the development of an appropriate methodology that mapped reported field data into a format usable by SEAS.

“Data triangulation” was another important aspect of the parameterization process. We compared data from a variety of sources with multiple perspectives to overcome the weaknesses and/or intrinsic biases that may exist in single-method, single-observer, and single-theory studies. Parameterization of traits, attitudes, and other parameters proceeded after multiple sources of information and data were compared, qualified and synthesized.

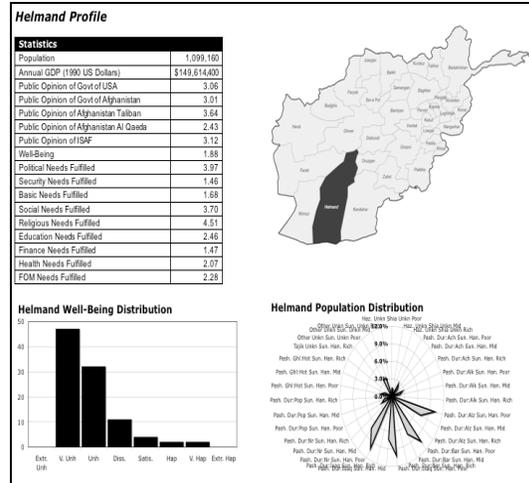
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<sup>1</sup> At the time of the creation of the reference world, the 2003 version of the NRVA was the latest version available. A 2005 version has subsequently been released, and a 2007/08 edition of the NRVA is currently in development.

For example, we relied on a number of public opinion polls to parameterize attitudes towards the Taliban. For instance, a December 2006 poll published by World Public Opinion.org noted that 90% of Afghans have a negative attitude towards the Taliban, while 94% have a negative attitude towards Al-Qaeda and its leader Osama Bin Laden. This report noted that *“Ninety-two percent of the Afghan people said their opinion of the Taliban was unfavorable, up four points from 88 percent in 2005. The numbers expressing a ‘very unfavorable’ view increased the most, rising 9 points from 62 percent to 71 percent. Only 7 percent expressed somewhat (5%) or very favorable (2%) views of the Taliban.”* Other surveys conducted by the Senlis Council and the United States Institute of Peace showed disapproval by approximately 72% of the population. From these three sources, data triangulation was used to deduce that between 72 - 92% percent of the population opposed the Taliban.

We also consulted other surveys to further parameterize attitudes across ethnicities, sects, and tribes/sub-tribes. For instance, a February 2007 CSIS report noted that *“most of the (Taliban) leadership is from the Ghilzai Pashtuns, including the charismatic leader Mullah Mohammed Omar, and its principle areas of operation coincides with the Ghilzai’s largest population centres in Uruzgan, Zabul, Ghazni, Dai Kundi, and Paktika.”* This information was used to parameterize attitudes towards the Taliban for non-Pashtun ethnicities, such as Tajiks, Hazaras and Uzbeks, non-Ghilzai Pashtuns (i.e. Durrani), and Pashtuns located in the northern parts of the country. Thus, the consultation of numerous sources of information facilitated data triangulation as well as parameterization at a fine level of detail.

Validation of generated data was the final step in the creation of the reference world starting point. This step was critical, because much of the detailed data produced by SEAS to populate the reference world does not have real-world counterparts for Afghanistan. Our validation efforts at this stage were focused on validating macro-level outputs for each of Afghanistan’s 34 provinces. For example, below is the SEAS provincial profile for Helmand province.



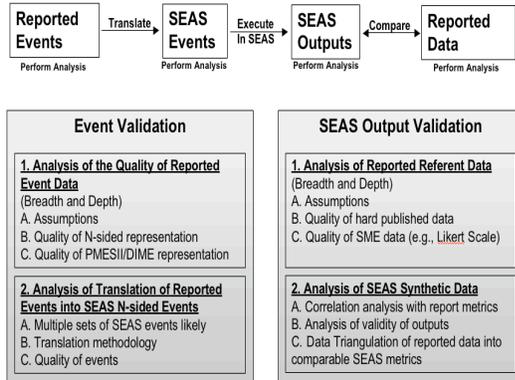
We validated macro-level synthetic data using sources that were not initially relied upon to create the generated data. For instance, we initially utilized data from the CIA World Factbook, Afghanistan’s Central Statistics Office and detailed National Geographic maps to determine provincial-level population as well as the religious and ethnic distribution within each province. We cross-referenced our initial calculations with the district-level profiles produced by the Office of the United Nations High Commissioner for Human Rights (UNHCR) as well as reports put out by think tanks such as CSIS. Any notable discrepancies were set aside for further review and evaluation.

Thus, the creation of the starting point for the reference world required the successful completion of three main tasks: (1) identifying, qualifying and synthesizing relevant sources of data and information; (2) developing a parameterization methodology to configure the traits and parameters of SEAS agents; (3) and validating the initial emergent data. We now turn to a description of our continuous validation effort.

**CONTINUOUS VALIDATION**

Once the initial state of the reference world was populated, parameterized and validated, the next step was to run the synthetic world forward in time with the injection of real-world events from March 2007 on, followed by an analysis of output data to determine the consistency between synthetic data and the actual state of the world (as perceived by Simulex analysts). At this point the validation phase was continuous, since end-users required that the synthetic environment accurately reflect real-world conditions within a 30-day period.

The continuous validation effort, as indicated in the diagram below, consisted of two main tasks, “significant event” validation and output validation.



We defined a “significant event” as a diplomatic, informational, military or economic action taken by one of the five Human-in-the-Loop actors configured for the SEAS virtual Afghanistan (see diagram below).

### Continuous Validation: Afghanistan Events

Example Hypothetical Matrix

|                  | Diplomatic            | Information            | Military                              | Economic                   |
|------------------|-----------------------|------------------------|---------------------------------------|----------------------------|
| Govt of USA      | Engage Govt           | Media Campaign         | Counter Insurgency, Poppy Eradication | Reconstruction, Relief Aid |
| ISAF             | Engage Govt           |                        |                                       | Reconstruction, Relief Aid |
| Govt of Afghan   | Engage Tribal Leaders | Media Campaign         | Counter Insurgency                    | Reconstruction, Relief Aid |
| Afghan: Taliban  |                       | Information Operations | IED, Attacks                          |                            |
| Afghan: Al Qaeda |                       |                        |                                       | Finance Taliban            |

The first step, therefore, was to identify and gather as much information as possible on the variety of DIME actions across all five HITL players. We consulted a number of sources to obtain data on significant events, such as the ISAF Press Office, the websites of the U.S. Embassy in Kabul and the Afghan Embassy in Washington, DC., Afghan government websites (Ministry of Foreign Affairs, Office of the President, etc.), Afghan news services (Pajhwok, Bakhtar News Agency), and Afghan-specific websites (Afghanistan page of IRIN, e-Ariana, Agha.com, etc).<sup>2</sup> In addition, we utilized daily situational reports from consultants based in Afghanistan to populate “M” (military) and

<sup>2</sup> The Integrated Regional Information Network (IRIN) is the humanitarian news and analysis service of the U.N. Office for the Coordination of Humanitarian Affairs.

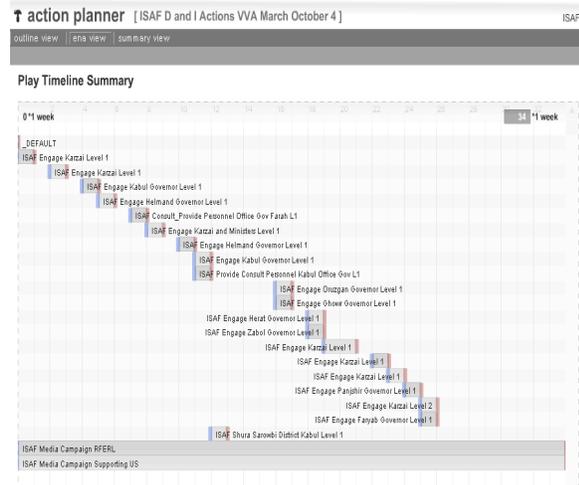
“I” (informational) actions for each of the five HITL players.

It quickly became apparent, though, that even with our best research efforts, we would not be able to capture every single significant event across all DIME actions and HITL players. The main problem was that many events, particularly those related to Taliban and Al Qaeda actions, are simply not reported with a sufficient degree of specificity by news services, websites and other sources of information. For instance, the following excerpt from a May 2007 article in the *New York Times* noted how the Taliban were able to siphon off profits from the opium trade in Afghanistan to fund their activities: “Farmers growing poppies in Taliban-controlled areas pay a tax to the insurgents, who then hire “day fighters.” For their part, drug traffickers pay the Taliban for security....In Nimruz province, in southwest Afghanistan, the Taliban demanded that traffickers provide \$4,000 a month and a Toyota Land Cruiser to support 10-man fighting units, according to United Nations officials. An Afghan official said Taliban forces were given five Land Cruisers for attacking the Afghan border police so traffickers could move drugs more easily....”

The above excerpt does provide some detail as to the location of these extortionist actions by the Taliban (Nimruz province), but Simulex analysts deduced that these actions were likely to be widespread in opium growing areas controlled by the Taliban. Based on an extensive review of available research and news reports, we also determined that other actions, such as Al Qaeda technical/media support to the Taliban, as well as the Taliban engaging and receiving support from friendly sub-tribes, were also likely occurring with a high degree of frequency despite the lack of media coverage or specific information in the media reports that did address these topics. Thus, the set of DIME actions used to run the referent world forward in time was adjusted to take account of events deemed by Simulex analysts to occur with a high level of frequency, despite the fact that such actions, due to their secretive nature, did not receive extensive media coverage.

The next step in the continuous validation process was to upload and translate these events into a format understood by SEAS. Formal procedures were established to handle both of these tasks. We uploaded events into SEAS using the SEAS Significant Event Inject tool and the SEAS Action Planner. Both were used to create a number of discrete and continuous events in SEAS for which information was collected. For instance, the website of the Office of the President of Afghanistan disseminates news releases describing

meetings between President Hamid Karzai with a variety of foreign dignitaries and officials. These types of events were entered into the SEAS Action Planner as an “Engage” action (see below).



The insertion of a significant quantity of events was handled by the SEAS Significant Event Inject tool, a spreadsheet-based database of specific classes of events and their associated metadata. This tool was designed to work with databases providing information on thousands of significant events. For example, on the website of the Afghan Ministry of Rural Rehabilitation and Development, one can access files showing the status of thousands of development projects carried out from 2002-2008. The SEAS Significant Event Inject Tool was designed to handle files such as these as well as similar files and databases from other sources.

We also needed to develop procedures for translating real-world events into SEAS actions. As previously noted, the website of the Office of the President of Afghanistan provides information regarding meetings between President Karzai and foreign leaders. These events were translated as an “Engage” action in SEAS. But SEAS actions are also characterized by the numeric “resource level” associated with them (in the case of the “Engage” action, the resource level reflects the degree to which one actor tries to sway another actor to adopt attitudes favorable to the former). Each action resource level has been calibrated for a specific real-world semantic, so each event was mapped to a resource level in SEAS accordingly. For example, if three or more diplomatic engagements occurred within a week, the resource level for the “Engage” action for that week represents a 2; otherwise it represents 1. Similarly, we also developed procedures to overcome other types of translation issues as well, such as allocating responsibility for military actions undertaken

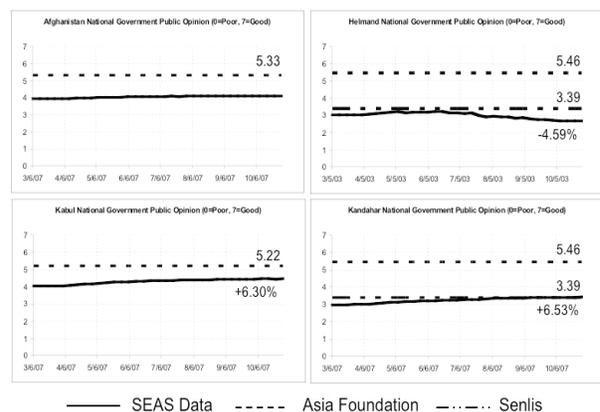
by “Coalition Forces” to the U.S., ISAF, or the Afghan government.

The final, iterated, stage of the continuous validation process was the evaluation of the goodness of fit between synthetic data and actual data and, if necessary, the recalibration of models and the resubmission of SEAS Action Planners for subsequent simulations over the desired timeframe. The key aspect of this step was the comparison of synthetic data from March 2007 on with actual data, and as a result the major challenge presented during this phase was the paucity of detailed, current data describing the economic, political and social conditions in Afghanistan, both nationally and at the provincial level.

Some of the critical values that we reserved for closer scrutiny included GDP growth and public opinion. We were not able to find GDP growth data for individual provinces, so we were left with validating GDP growth at the national level. We used real GDP growth rates from IMF country reports as our benchmarks, and calibrated the synthetic Afghan economy so that synthetic growth rates matched the growth rates reported by the IMF.

There was also a paucity of public opinion data. As previously noted, we relied upon surveys sponsored by several organizations, but these surveys occurred relatively infrequently (about every 8-12 months). Therefore, we had to rely on only one or two data points per year, and as a result our strategy of validating public opinion data essentially consisted of comparing trends in synthetic data with those seen in what actual data was available.

The diagram below shows a comparison of synthetic public opinion data with actual public opinion nationwide in Afghanistan as well as in Kabul, Kandahar and Helmand provinces:



Inconsistent trends between synthetic and actual data were set aside for further review. If the synthetic data could not be validated, subsequent iterations of model recalibration and the resubmission of courses of action ensued, with the current iteration of the continuous validation process ultimately ending only upon the validation of the generated data.

## CONCLUSION

As a result of specific customer requirements specifying that economic, political and demographic data not be more than 30 days out of date, Simulex, Inc. developed a continuous validation process for “virtual” Afghanistan designed to ensure that its family of models accurately reflected the state of the world as interpreted by Simulex analysts.

This process consisted of two main stages: an initial configuration and validation of a “Reference World” designed to mimic actual economic, political and demographic conditions in Afghanistan, and a continuous validation of this environment, with data updated, refreshed, calibrated and validated within one month of the current date. Once the reference world was populated and validated, multiple courses of actions for all five HITL players were submitted, with the generated synthetic data evaluated against actual data (to the extent that such data existed). Inconsistencies were set aside for further review, perhaps resulting in model recalibration, with the current iteration of the continuous validation effort ending only when synthetic data was successfully validated against real-world data.

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