Wargaming with PMESII

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ABSTRACT

Providing a comprehensive planning and decision support framework appropriate to today's complex operational environments requires a shift from the traditional approach of single-scope, military wargaming. To fully capture the operational environment requires the representation of a multi-sided political, military, economic, societal, information, and infrastructure (PMESII) framework that can be integrated to support course of action (COA) development for Wargaming, Mission Rehearsal and analysis. This integration must be across diverse domains, span local to global scopes, and allow for excursions over different time durations and geographical regions. Such an integrated adaptive planning environment is a many-sided approach allows a user to plan the actions of any entity in the environment and at any scope.

The core simulation technology described herein consists of the Synthetic Environments for Analysis and Simulation (SEAS — an agent-based model), and the Integrated Gaming System (IGS — the DoD Adaptive Planning and COA analysis tool), linked together in a Society of Systems (SoS) that integrates the heterogeneous simulations into a single experimentation environment.

This paper describes how a multidisciplinary team developed this integrated planning and experimentation framework using the SoS approach. Further, it describes the employment of this framework to support the training objectives of both the USMC Command and Staff College's Nine Innings Exercise and the U.S. Army War College's Strategic Decision Making Exercise, two wargaming environments intended to provide current and future decision makers an appreciation of the utility of PMESII Modeling and Simulation as a key element of the planning process.

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INTRODUCTION

Today's military planners require complex models of relevant population centers to develop and test strategies and counterstrategies from all competing sides. These strategies must allow for actions beyond traditional military actions to be undertaken, against both military and non-military entities, across the range of temporal, spatial, and population granularities involved (where population granularity is the amount of aggregation of human entities, such as an individual, tribe, city, or military organization.). The testing of these strategies can be associated with experimentation, where the experimenters explore emerging strategies via an ability to expand the set of warfighting capabilities within the complex synthetic environments, which include representations of relevant population centers.

New capabilities can be discovered through the development of network-centric operational concepts. Some of these concepts address on how best to influence a society towards some desirable end state. These same concepts are framed in the cultural context supplied by the societies that could be found anywhere in the World. These experiments address concepts from tactical to the strategic level, and may require a planning capability to investigate historical and forecast scenarios at multiple levels of geographic focus. The limited expertise available and the time it takes experts to conduct investigations, make the use of models, to emulate and highlight cultural differences that influence Political, Military, Economic, Societal, Information, and Infrastructure (PMESII) outcomes, a method for conducting the in-depth experimentation.

Once strategies and associated courses of action (COA) have been developed, planners require the ability to test these strategies and evaluate COAs in an environment unbiased by cultural or societal differences. Wargames provide the ability for multiple sides to be represented, and in such a wargame, the use of modeling and simulation has become increasingly valuable in order to fully evaluate the impact of Diplomatic, Information, Military, and Economic (DIME) actions on adversary PMESII systems.

This project was initiated as an experiment to address the DoD common gap to improve PMESII Modeling and Simulation (M&S) in the modern operational environment. The project was further intended to prototype how relevant culture-specific human behaviors can be factored into PMESII representations of the battlespace to support planning, Then how these representations can be visualized when, where and by whom to employ a comprehensive approach in two wargames to determine methods which could potentially deter a crisis rather than having to prostitute a military action.

INTEGRATING MODELING AND SIMULATION IN SUPPORT OF COMPREHENSIVE PLANNING AND WARGAMING

The core technology employed in this project consists of the Synthetic Environments for Analysis and Simulation (SEAS) and the Integrated Gaming System (IGS), collaborating together as a Society of Systems (SoS) to provide a single planning and experimentation environment. The SEAS-IGS Society provides an integrated planning and experimentation environment that facilitates experimentation in an efficient and scalable manner. Bridging the runtimes of SEAS and IGS simulations provides a synthetic environment that incorporates both population behavior and military operations as well as relationships and conflicts that emerge as the multi-perspective plans are played out.

Synthetic Environments for Analysis and Simulation (SEAS)

SEAS includes the Virtual International System (SEAS-VIS)[1], which is a robust, comprehensive, scalable, agent-based infrastructure for persistent synthetic environments. SEAS-VIS was designed to provide decision makers with a continuous experimentation platform for evaluating how Diplomatic, Information, Military and Economic

elements of national power can be effectively utilized across the spectrum of conflict. SEAS-VIS provides a framework that is unbiased towards any one specific scenario, model, or system and can be used to represent fundamental human behavior theories without restrictions on what can be modeled, uncommon in today's simulation efforts.

The SEAS-VIS framework is unbiased towards any specific scenario, model, or system, and can be used to represent fundamental human behavior theories without restricting models to a specific design or granularity of representation. SEAS-VIS currently includes 62 nations, hundreds of named organizations and leaders, thousands of infrastructure nodes, and hundreds of media nodes and produces a high fidelity representation of societal interactions that incorporate local interactions and up to national and global level relationships.

The enabling technology of SEAS consists of three core components: the SEAS-VIS Engine, an ontological knowledgebase called the Extensible Net Assessment (xNA), and SimBridge which implements a Society of Systems approach to integration. SEAS-VIS is integrated with other simulations and components, such as integration with a military simulation in support of military scenarios. While military simulations are best sued to model military units and their associated activities, non-military units may be better represented in non-traditional military simulations. Statistics calculated from a SEAS simulation are then used to provide measurable evaluations of strategies spanning diplomatic, information, military, and economic realms for providing the necessary intellectual underpinnings to support all the forms of effects-based thinking used to aid decision makers .

The Integrated Gaming System (IGS)

The Integrated Gaming System (IGS) is a state-of-the-art toolset capable of addressing a wide range of issues (e.g., course of action and concept development and analysis, and capability trades or technology enhancements). IGS provides military and civilian planners with the ability to develop multiple courses of action in a distributed manner, providing geospatially-referenced estimates of combat- and non-combat related insights as they relate to the Human/Societal, Informational, and Physical dimensions of the complex operational environment, across all phases of conflict. With the primary components that make up IGS (Scenario Tool, Campaign Planning and Rehearsal System, and the Entropy-Based Warfare Model)[5] IGS provides scenario generation, planning and rehearsal, adjudication, and communication capabilities in a single, integrated architecture, supported by a common database. Using IGS planners and analysts have the means to compare alternative scenarios, assumptions, and conceptual dependencies as part of Course of Action (COA) development. This type of analysis, with an embedded geospatial visualization capability, can then be leveraged as a decision support tool or as a training vehicle for planners for operations ranging from force employment (including combat and non-combat actions of military and non-military forces), theater security cooperation, strategic communications, post-conflict stabilization and reconstruction, to humanitarian assistance / disaster relief.

IGS has the capability to read in various databases (e.g., Intelligence Community's Modernized Integrated Database [MIDB], USJFCOM's Operational Net Assessment [ONA] database), SEAS's xNAand near real time data feeds such as Blue Force Tracker to assist in order of battle and plan development. IGS also shares information with the following other tools:

- Collaborative Force Analysis, Sustainment, and Transportation (CFAST)
- Joint Semi-Automated Forces (JSAF)
- Satellite Toolkit (STK)

Society of Systems (SoS)

The runtime execution of an experiment occurs using a Society of Systems (SoS)[2,3] approach. A SoS is analogous to a society of people, as both are loosely coupled constructs in which independent individuals contribute toward a single societal identity. A Society is an organized group of individuals who associate for common purposes. Simulations, database servers, and other system components make up the Members of a SoS. Each Member is autonomously managed and cooperates with other Members to reach its personal goals. In the process of meeting its personal goals, a Member contributes to societal goals. Modeling of the Society emerges as a result; the summation of the resultant Members' behaviors become in essence a depiction of the society's culture.

Members in a Society share aspects of their representations of reality with other Members. These shared aspects make up the Shared Reality component of a SoS. All data exchange occurs within Shared Reality. Unlike traditional approaches to integration, Shared Reality is not a centralized management layer. Rather, Shared Reality is only tasked with facilitating distributed and asynchronous access to information.

Each Member in a Society accesses Shared Reality through a Member-specific Liaison. A Liaison consists of the intelligence needed to interact with and control a Member and to interact with the rest of the Society. A Liaison is configured to use Member-specific mechanisms, such as initializations, inputs, outputs, and control mechanisms. In this way, the same Member can be used in different Societies and be continuously developed without being forced to address Society-specific characteristics, enabling reuse and independent development.

Data exchange occurs among Members in a semantics-based manner whereby a Liaison uses the ontological specifications to determine which translator to employ to translate from a producer's semantics into a form its Member can consume.

A key aspect that differentiates a Society approach to system integration from other approaches is that the linkages among the Members emerge as opposed to requiring a full specification of an engineered network. In the organizational language of a society, satisfaction of societal goals emerges as all Members progress towards their personal goals. Since these linkages manifest themselves over discrete time intervals, a temporal aspect is also important, and why is accounted for in the xNA ontology. This temporal aspect is significant when building and maintaining persistent environments, where Member history is important for execution and forecasting of potential Member activities.

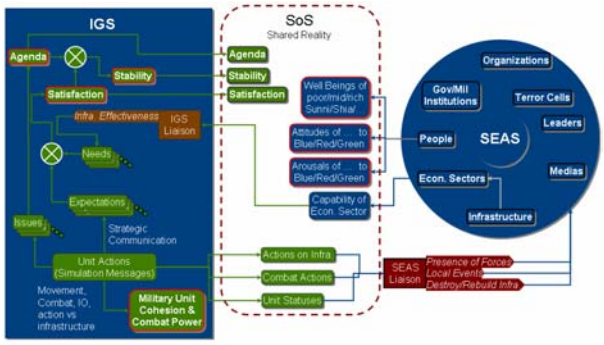

Figure 1. The SEAS-IGS Society of Systems

The SEAS-IGS Society

At the time of constructing the SEAS-IGS Society, both IGS and SEAS were mature technologies that had been integrated with various other tools and simulations. Planning and coordination meetings were held prior to designing the technical integration of IGS and SEAS to determine how the strengths of the two simulation systems could best support the overall goals of the integration, which was to model irregular warfare in the context of dynamic PMESII behavior. Figure 1 depicts the overview of the SEAS-IGS Society.

The content of the data exchange among IGS and SEAS was designed for reuse by enabling data to be produced in a manner that is independent from how it is consumed. General XML schemas were developed to describe state of entities in IGS that impact the behavior of entities modeled in SEAS-VIS and the statistics of SEAS-VIS data used by IGS entities to sense economic and population conditions. The data exchange schemas were designed to eliminate dependencies on temporal and geographical granularities so that design decisions of SEAS developers would not interfere with the design of IGS and visa versa. The data exchange schemas were kept current with changes throughout the project. The following XML sample describes an IGS Infrastructure entity, which is one piece of information IGS shared with the society.

```
<IGSInfrastructure>
    <trait ID="ObjectID" value="240E1330"/>
    <trait ID="Name" value="Health Services,
        VIII-Eastern Visayas"/>
    <trait ID="Time" value="2008-01-
        02T00:00:00"/>
    <trait ID="ObjectType"
        value="Infrastructure"/>
    <trait ID="Region" value="65"/>
    <trait ID="InfrastructureType"
        value="Health Services"/>
    <trait ID="Latitude" value="11.230925"/>
    <trait ID="Longitude" value="124.984472"/>
</IGSInfrastructure>
```

The **ObjectType** identifies the entity as infrastructure, population, a leader, or a military unity. The economic sector the infrastructure was associated with was specified in the **InfrastructureType**, which was one of oil, power, natural gas, telecommunications, water, military industrial, transportation, manufacturing, agriculture, finance, education, and health services. For infrastructure entities, the region tag identified the geographical area the infrastructure entity was representing.

Because the data exchange construct followed a simple yet robust format, the current implementation is fundamentally identical to that of a year and a half ago.

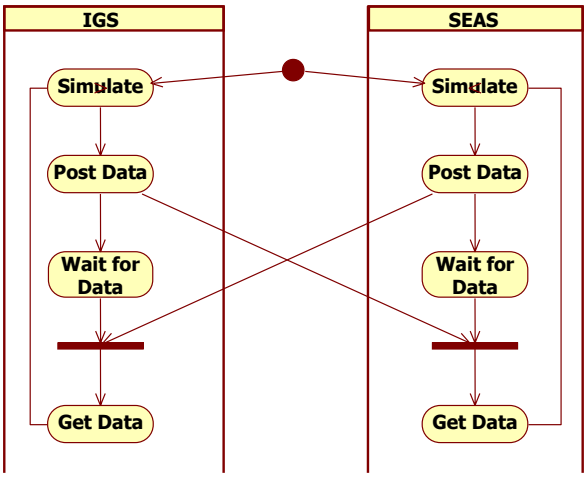

Figure 2. Time Synchronization of IGS and SEAS

With the logical entities of the data exchange agreed upon, the IGS and SEAS engineers developed service-based data exchange processes for the integrated society to enable truly portable execution across the Internet. The design a high level state view of the synchronization between IGS and SEAS is illustrated in Figure 2. IGS and SEAS operated at different temporal granularities and had diverse computational requirements. The time synchronization was designed so that SEAS-VIS would always follow IGS in advancing simulation time.

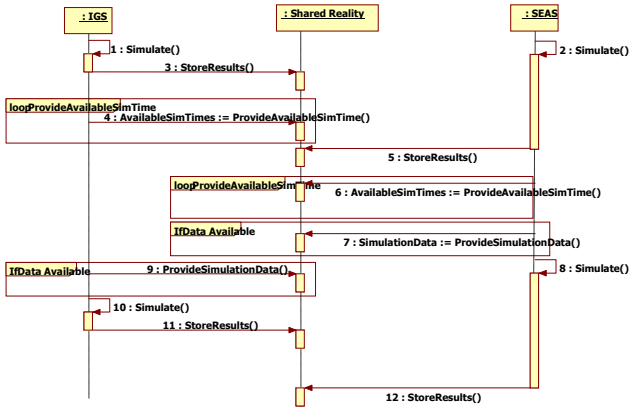

Figure 3. Data Exchange of Shared Reality

The data exchange was further developed to facilitate a service-based integration, as is illustrated in Figure 3.

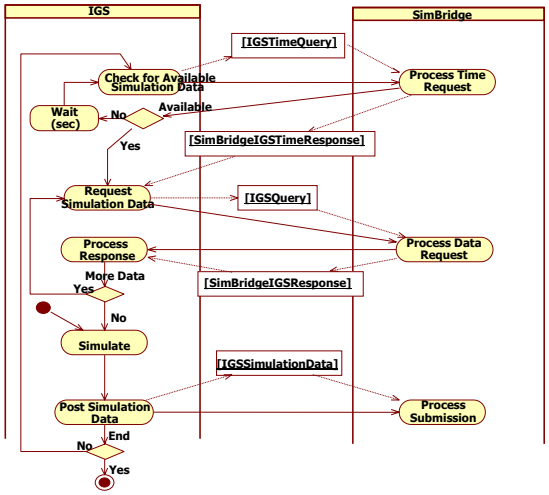

Figure 4. Design of the IGS Liaison

The Society approach to integration facilitates independent development. Engineers for IGS and SEAS could then develop their own internal processes and implementations using the Liaison construct without interfering with each other's design decisions. Figure 4 is an activity diagram depicting the implementation of the IGS Liaison.

Using the XML schema to communicate with Shared Reality, the IGS-Liaison seeks for all data in Shared Reality that indicate the effectiveness of infrastructure. Any infrastructure capability statistics produced by SEAS that are discovered are converted to match the granularity of IGS and transformed in order to be consumed by IGS. Additionally, the IGS-Liaison queries Shared Reality for population well being, attitude, and arousal statistics and maps these to the decomposition of population represented in IGS. The appropriate mapping is performed by searching for statistics constrained by key distinguishing traits of the population, such as religion and income class.

Military unit actions to rebuild or destroy infrastructure are simulated in IGS and shared in Shared Reality. The SEAS Liaison senses any such actions and applies them to infrastructure entities in SEAS. Infrastructure in IGS is represented as aggregations of all infrastructure of a particular type in a geographical region. SEAS represents infrastructure by representing a sampling of individual physical structures. To apply actions originating from IGS on SEAS entities, the actions on aggregated infrastructure were disaggregated and applied to infrastructure of a particular type depending on the percentage of infrastructure that the IGS aggregates represent. The translation occurs transparent to IGS according to the

SoS approach, which is producer friendly, placing the load of translation on the consumers.

Any tactical activities by military units that can be sensed by a population are also shared between IGS and SEAS. The components in IGS compute the execution of such activities and the IGS Liaison shared the events with Shared Reality. In turn, the SEAS Liaison senses these military events, which enables the population and information networks to form and propagate their perspectives on the scenario, encompassing both military and civilian behavior, as the scenario unfolds.

Testing

Testing was always conducted in a distributed manner between McLean Virginia, the USJFCOM in Suffolk, Virginia, and Simulex in West Lafayette, Indiana. Due to the design, the Liaisons were configurable to pass through the appropriate firewalls when needed. Multiple iterations of each scenario were tested to ensure the proper effects were registered by each simulation, properly attributed, and properly applied to the internal simulation metrics. Depending on the event, testing usually lasted between two to three weeks. The first successful IGS-SEAS data exchange took place approximately two months after development began.

Extensibility

Due to the support for extensibility in a Society approach to integration, additional capabilities can be added to the IGS-SEAS federation without significant design modifications. Depending on the nature of the change, a modification may need to be made to the XML schemas, the simulation behaviors, or both.

Extending a society to include other simulations or reusing the integration components in a different society would follow the straight-forward steps described above. Introducing a simulation or tool that views, manipulates, or correlates existing shared data can be performed with little or no modification to the existing integration framework. If a simulation to be added may produce new impacts on the behaviors of IGS or SEAS, then a re-examination of the data exchange processes must be performed and the new information will require a representation in shared reality. This must be done to ensure the newly formed federation operates properly and operates at optimal performance. This extending of the existing framework is analogous to extending the Federation Object Model (FOM) as in the High Level Architecture protocol.

WARGAME SUPPORT USING PMESII MODELING AND SIMULATION FEDERATION

Nine Innings

Having developed and tested the IGS-SEAS society, the integration effort turned to a wargame support effort. The first wargame environment chosen as a test bed for the new PMESII M&S Society was the Marine Corps Command and Staff College's 2007 Nine Innings Exercise, which is the capstone exercise for the student body. Nine Innings is a large-scale wargaming effort, involving two Joint Interagency Planning Groups, each with over 100 participants and five distinct player cells aligned in logical lines of operation (Security/Governance, Economics, etc). In the 2007 exercise, student planning groups were tasked to develop an eight year security cooperation plan for the Philippines, from a US Pacific Command perspective. Half a dozen SEAS-IGS operators were supported by less than a dozen student M&S liaisons, responsible for ensuring the plans from each of the individual lines of operation were properly represented within the M&S environment.

During the exercise, using open source data, the SEAS-IGS society was able to support System Framing, COA development, COA Wargaming, and final plan development. Products provided to the students included Geographic Information System (GIS) overlays in IGS (Demographics, economics, etc), Initial attitudes and well being of Philippines population (Mega-region level), Economic sector health (effectiveness of Philippines infrastructure / economy at the Mega-region level), and Force postures of Philippines armed forces, national police, U.S. and regional military forces, and all insurgent/separatist groups. Using the SEAS-IGS environment, students were able to develop their engagement plans, test their sufficiency, and modify plans based on results of internal wargaming and the indications provided by the M&S environment as needed. The SEAS-IGS society supported the plan-wargame-plan approach, which enabled the students to design a campaign plan focusing on all elements of the PMESII spectrum.

As Nine Innings is designed as a 'living exercise" the SEAS IGS society also enabled real world events to be injected, including a Texas Instruments $1B semiconductor plant in Clark Special Economic Zone, Jamaat al Islamiya-attributed bombing on Mindanao, and elections and pre-election violence. The flexibility of the environment also enabled Master Scenario Event List (MSEL) Injects, including a forecasted economic downturn, periodic election violence, and Coalition exercises to be included as external stressors. Finally,

the results of the combined IGS-SEAS model runs, in geospatial overlay and time phased graphical outputs were made available to the students and mentors.

Army War College Strategic Decision Making Exercise

As Nine Innings concluded and the efforts were socialized among the M&S community, another opportunity emerged to test the PMESII Decision Support environment. The US Army War College's (USAWC) Strategic Decision Making Exercise (SDME) is the annual capstone exercise for USAWC students; it challenges them with a variety of conflicting situations across the DIME / PMESII spectrum. Strategic combat and logistics models have typically lent rigor and credibility to the exercise, while subject matter experts have provided PMESII inputs and effects.

For SDME 2008, USAWC Staff solicited the SEAS-IGS society as a means to provide similar rigor and credibility to the PMESII aspects of one challenging scenario[6]. Set in a notional future Cuban environment, the inherent capabilities of the SEAS-IGS society enabled the team to rapidly create an 2021 scenario leveraging existing environments in IGS and SEAS. The team simulated Semester One events and their impact on the population and infrastructure (road to war + 60 days combat) using MSELs provided by USAWC faculty. This modeling was necessary in order to establish the initial conditions inside IGS-SEAS society for Semester Two M&S. The second Semester work examined the effect on population well being and attitudes for three different six- month duration SSTRO/PKO scenarios: US-Led Security, Stability, Transition, and Reconstruction Operations (SSTRO)/ Peace Keeping Operations (PKO), UN- or Organization of American States (OAS)-Led SSTRO/PKO, and Cuban Government left to handle reconstruction internally. Unlike Nine Innings, where the M&S was exercised during the event at pre-determined instances, the M&S support to the SDME was conducted months in advance of the exercise, in order to provide risk calculus insights to SDME faculty and participants. USAWC staff evaluating the M&S results felt the intuitive graphs and geospatial metric overlays and associated insights were intuitive and supported learning points. Overall the PMESII models reinforced scenario credibility by independently producing COA results consistent with learning points. This effort, along with recommendations for future employment, was briefed at the 76th MORS Symposium in New London, Connecticut in June 2008[6].

SUMMARY AND WAY AHEAD

This project demonstrated the value of linking M&S tools (IGS and SEAS) to support comprehensive DIME/PMESII Planning and Decision Support in support of wargaming and training environments. Support to USMC Command and Staff College's Nine Innings highlighted the flexibility of the PMESII M&S tools to examine operational planning needs in a complex adaptive planning environment that combat simulations alone could not. Similar support to the U.S. Army War College's Strategic Decision Making Exercise preparation efforts stimulated discussion about outcomes and causality among the faculty. As a key wargame designer in Carlisle wrote in his assessment of the Federation: "These are exactly the kinds of thoughts & discussions we want to stimulate with the students."

Though the IGS-SEAS PMESII Federation has set a standard for web-enabled environments supporting comprehensive PMESII modeling and simulation, several potential enhancements merit consideration. In addition to technical enhancements to further enhance the linkage between the simulations, the Society of Simulations approach employed makes possible the rapid addition of other simulation capabilities in order to further improve PMESII Modeling and Simulation (M&S) in the 21st century operational environment.

Jointly, this approach has the potential to improve the methods for United States governmental agencies to better interact among themselves and help bring inputs from non-governmental entities to help forecast societal behaviors of nation-states, trans-national actors, and otherwise unpredictable enemies.

Applicability beyond DoD, into Federal, State and Local domains is therefore facilitated through the SoS semantic integration approach and the flexibility of the PMESII M&S tools, and as such, related opportunities for application of the PMESII M&S society include semantic integration with other simulations for Homeland Defense and Defense Support to Civil Authorities.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the support of the Modeling and Simulation Coordination Office and the United States Joint Forces Command J9 for their support and guidance provided over the conduct of this effort, and the United States Marine Corps Command and Staff College, and the United States Army War

College for their willingness to open their wargaming events to be used as prototype test beds for this effort.

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