

On Adding a Fourth “Artificial” Simulation Environment Category to the Live-Virtual-Constructive Simulation Environments

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Abstract—So called Live-Virtual-Constructive simulation environments are used as test and validation tools for three combinations of real or simulated people working with real or simulated equipment: Live accommodates real people in real equipment, Virtual accommodates real people in simulated equipment, and Constructive accommodates simulated people in simulated equipment. The work here suggests and investigates a fourth “Artificial” environment accommodating simulated people (e.g., AI pilot) in real equipment. The simulated people, in the context of this paper, refer to the artificial applications that will operate the agent in the simulated environment. Autonomous and cognitive applications like these are expected to respond effectively to uncertain and changing environments.

Six characteristics; Flexibility, Intelligence, Cognizance, Collaboration, Autonomy, and Artificiality are identified to propose a reconfigurable architecture of concepts and capabilities for such an environment. With this initial platform, subsequent research and refinement of Artificial Simulation Environment practices should help overcome the constraints and fears that impede deployment of autonomous and cognitive systems. This work also suggests that investigations of the remaining two combinations of real/simulated people/equipment simulation environments are warranted.

Index Terms—evaluation, modeling, multi-agent systems, simulation, testing

I. INTRODUCTION

Intelligent systems must be designed so that decision makers will trust them and therefore use them appropriately [1]. This sense of risk is compounded with the difficulty to control emergent behavior [2] when such systems are expected to work together autonomously in groups. The acquisition and implementation of intelligent systems is swiftly increasing and decision makers are requiring innovative ways to test and evaluate intelligent systems prior to their deployment. The focus of the intelligent systems for this paper is on unmanned systems in test and evaluation. According to the 2006 Quadrennial Defense Review (QDR) Report [3], the Department of Defense (DoD) “will increase procurement of unmanned aerial vehicles to increase persistent surveillance, nearly doubling today’s capacity” The QDR also states, “Approximately 45% of the future long-range strike force will be unmanned” [3]. These unmanned systems are taking over the dull, dirty, and dangerous task typically

conducted using manned systems in the five operational domains of space, undersea, sea surface, ground, and air.

Although the use of these unmanned systems is increasing, decision makers lack trust and confidence in the systems and may either not employ them correctly or trust them more than they should. The lack of trust stems from these unmanned systems behaving in strange and unexpected ways (emergent behavior) when tasked to work together. This paper suggests adding a fourth “Artificial” simulation environment to the current backbone of the Live-Virtual-Constructive environment: Live accommodates real people in real equipment, Virtual accommodates real people in simulated equipment, and Constructive accommodates simulated people in simulated equipment. This fourth environment accommodates simulated people in real equipment and is an approach to test and evaluate these emergent behaviors to foster trust and confidence of decision makers in unmanned systems.

The Artificial Simulation Environment (ASE) can aid in the study of how emergent behaviors take place when these systems are required to make autonomous decisions based on the interaction with other agents. Features and patterns recognized by the ASE can benefit the community of interest by using the ASE to discover and understand the concepts and designs needed to allow these intelligent agents to perform complex operational missions. Controlling and coordinating are important for effective deployment at the operational level. One of the most important reasons to adapt the ASE is to allow rapid and reliable testing and evaluation to support the war fighter. The environment provides interface mechanisms and methods for agents to interact with each other to include whatever apparatus the agent is going to control.

The rest of this paper’s organization is as follows: Section II gives background information on the Live, Virtual, and Constructive modeling and simulation environments and discusses three additional simulation environments. Section III provides an overview of the fourth “Artificial” Simulation Environment and examines the six characteristics associated with the ASE: Flexibility, Intelligence, Cognizance, Collaboration Autonomy, and Artificiality from the agile Response Ability Process assessment. Section IV describes the reconfigurable architecture and concept of operations of the ASE. The conclusion and suggested areas of research are contained in Section V.

II. BACKGROUND

Modeling and simulation is an art as well as a science and involves many tools and creative minds to succeed. Traditionally, the training, test, and evaluation communities recognize three areas, Live, Virtual, and

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Constructive systems in simulation environments. The three components (Figure 1) of these environments are the person, equipment, and medium. The person and equipment may be simulated or real while the medium is either physical or computerized.

Using real people operating real equipment in a physical environment is live simulation. The use of scenario based live simulations is commonplace and presently the preferred method of training soldiers for operations [4]. An example is a pilot operating a real aircraft over a test range. Virtual simulation provides crews, leaders and units with realistic training experiences using sophisticated simulators where real people operate simulated equipment in a computerized environment. The example is a pilot operating a flight simulator. Constructive simulation uses computer models and involves simulated people operating simulated equipment in a computerized environment. An example is a simulated aircraft entity operating in a computer simulation.

Figure 1, The Simulation Environment Matrix, illustrates six environments adding Man-in-the-Loop (MIL), Hardware-in-the-Loop (HIL), and ASE to the Live-virtual-Construct environments.

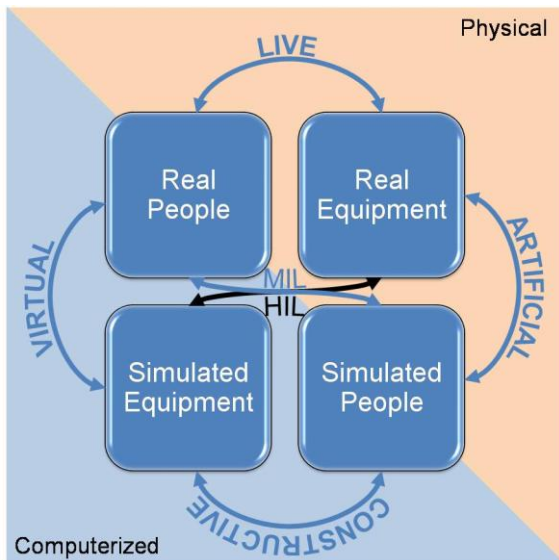


Fig. 1: Simulation Environment Matrix

MIL is real people controlling simulated people in a computerized environment. An example is a pilot controlling a simulated pilot in a computer simulation. HIL is real equipment acting as simulated equipment in a computerized environment. Example is a navigation box reacting from a simulated navigation box in a computer simulation. The distinction is the boxes never know if they are in a physical environment. The ASE is simulated people operating real equipment in a physical environment. Two documents discovered during the research support the concept of a different type of simulation known here as the ASE. The Modeling and Simulation glossary points out the exclusion of a category of simulation where simulated people are working real equipment [5]. The Modeling and Simulation Body of Knowledge refers to a virtual pilot in using modeling and simulation for decision support [6]. An example of the ASE is multiple autonomously controlled

unmanned systems operating on a test range for analysis of an algorithm for collision avoidance.

The DoD Unmanned Systems Safety Guide for Acquisition defines an unmanned system as: “An electro-mechanical system that is able to exert its power to perform designed missions and includes the following: (1) there is no human operator aboard, (2) unmanned systems that can be fully or partially operated in an autonomous mode, and (3) the system is designed to return or be recoverable” [7]. Webster’s defines unmanned as without the physical presence of people in control. A system is a “set of components (subsystems, segments) acting together to achieve a set of common objectives via the accomplishment of a set of tasks” [8]. Can these subsystems or segments think?

Alan Turing discussed the notion of “can a machine think” in the 1950 article “Computing Machinery and Intelligence” [9]. One concept from the paper was the Turing Test. The Turing Test sought to discover if an interrogator in a separate room from two subjects (a man and a woman) could tell which of the subjects the woman was. In the context of this paper, the Turing test would be whether a decision maker would know if a human were controlling the unmanned system. John Searle did not agree with the Turing Test as a method to establish a machine’s ability to demonstrate intelligence. Table 1 lists other objections Turing decided to confront in his paper.

Table 1: Objections to Turing Test

OBJECTION	RATIONALE
Theological	No animal or machine can think
Heads in the Sand	Machines thinking is dreadful
Mathematical	Limited power of discrete-state machine
Consciousness	Should the machine be conscious
Various disabilities	Can never make a machine do “X”
Lady Lovelace’s	Machines cannot originate anything
Continuity in the nervous system	Impossible to model nervous system
Informality of behavior	No set of rules for every situation
Extra sensory perception	Telepathy, clairvoyance, precognition and psycho-kinesis

Searle’s Chinese Room argument comprises a thought experiment and associated arguments which attempts to show that a symbol-processing machine like a computer does not have a mind or understand regardless of how intelligently it may behave. The Chinese room suggests that a computer cannot think simply because it can sort Chinese characters based on a set of programmed rules. Searle’s argues that if he was put in a room and fed Chinese characters and a set of rules he could sort the characters but not speak or understand a word of Chinese [10]. So how will one measure if the intelligence agents understand each other and can comprehend a situation?

Theory of Mind is the understanding of the mental states of others, including their intentions, desires, beliefs, and emotions [11]. Encompassing emotions of Theory of Mind into the ASE will require research beyond the scope of this paper. The Belief-Desire-Intention (BDI) model [12] demonstrates the possibility that the ASE could recognize

the intentions and desires of entities operating within the environment. An example is disseminating route plans (intent) to agents for safe flights (desire) to avoid collisions (goal). One drawback to the BDI philosophy is the use of open-loop decision-making [13] where an event is required to achieve a goal. The proposal here is to use a close-loop decision-making process to feedback actions within the environment. In a close-loop ASE, no event is needed such as two entities to close to each other, to trigger the goal to avoid collisions. The ASE would monitor entities and adjust routes to preventing entities to get too close to each other thus avoiding collisions.

The research of Rodney Brooks [14] demonstrated that the behaviors do indeed emerge. Furthermore, we will never understand how to decompose human level intelligence until we have had a lot of practice with simpler level intelligences. Build each piece of the complete system incrementally and at each step of the system and its interfaces are tested and evaluated. Test the complete intelligent systems in the real world with real sensing and real action. Conclusion of research by Brooks follows: “When we examine very simple level intelligence, we find that explicit representations and models of the world simply get in the way. It turns out to be better to use the world as its own model” [14]. The idea to investigate the ASE as a method to test and evaluate intelligent systems is supported by Brooks’ belief to test intelligent systems in the real world. The notion of systems using embedded intelligence to control a piece of a system is not new. The suggestion to have an environment to allow testing and validation of intelligent agents operating and managing real equipment is new.

III. INVESTIGATING A FOURTH ARTIFICIAL ENVIRONMENT

This suggestion formulates the foundation of the ASE, Agile Emergent Behavior (Figure 2). Because these intelligent agents will exhibit non-obvious, not-explicitly-programmed behavior when they get together, the environment should manage and apply knowledge to analyze the emergent behavior. When someone you have known for years exhibits uncharacteristic behavior at a party, did the environment cause the behavior or the group? Agile Emergent Behavior is different from emergent behavior because the agility is expressed as the ability to manage and apply knowledge effectively, so that an organization has the potential to thrive in a continuously changing and unpredictable environment [15]. Emergent behavior can appear when a number of intelligent agents operate together in an environment, forming behaviors that are more complex as a group such as the party example from above.

The characteristics of the ASE are Flexibility, Intelligence, Cognizance, Collaboration, Autonomy, and Artificiality (FIC²A²) (Figure 2).

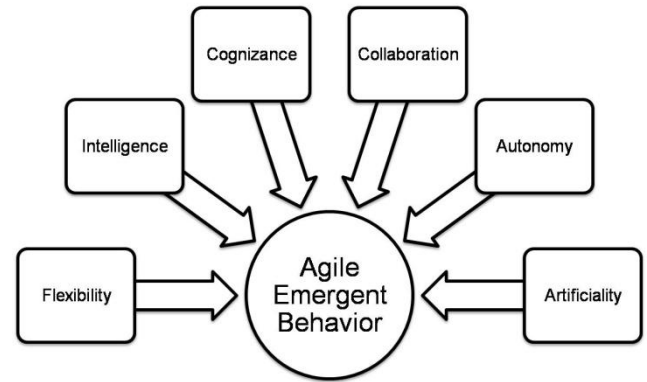


Fig. 2: Characteristics of the ASE

The ASE models and displays these characteristics to allow the environment to recognize and analyze agent capabilities. These characteristics are the guidance needed by anyone who would develop agents that will operate in such an environment. Next is the explanation of each of the FIC²A² characteristics.

A. Flexibility

Various fields define flexibility differently. Manufacturing systems define flexibility as “the ability of the system to adapt itself to the various changes” [16]. The definition of flexibility in Information Technology is “the ability to vary the “reach” of technology, to vary the “range” of technology features, and to use “time” as an ally in the quest for flexibility” [17]. Similarly, Nilchiani defined flexibility in space systems as “the ability of the agents to respond to potential internal or external changes affecting its value delivery, in a timely and cost-effective manner” [18]. Encompassing the aforementioned definitions, Flexibility, in the ASE, is adapting the reach and range of the agent’s technology features to respond to internal or external changes unforeseen in the agent’s design. With a definition of flexibility for the ASE, we can look to identifying the different types of flexibility for the ASE. Browne et al [19] identified eight types of flexibilities for manufacturing systems: Machine, Process, Product, Routing, Volume, Expansion, Operation, and Production. Browne’s definitions centered on the amount of automation and the diversity of the parts for the manufacturing systems. Faulkner [20] identified six types of flexibility, Process, Product, Routing, Volume, Expansion, and Production. It is proposed that the ASE concept employ the eight types but centers around the level of automation and the diversity of data. Table 2 shows a comparison of the definitions.

Table 2: Definition Comparison of Browne, Falkner and FIC²A²

Type	Browne/Falkner	FIC ² A ²
Machine	Changes required to produce a given set of part types	Different roles the agent can perform
Process	Produce a given set of part types	Handle different types of information
Product	Changeover to produce a new product	Process different data sets
Routing	Handle breakdowns and continue to produce given set of part types	Ability to change course or mission
Volume	Operate at different production volumes	Storage capacity
Expansion	Capability of building a system and expanding it	Adding capability to agent
Operation	Ability to interchange ordering of several operations for each part type	Ability to accept new tasking
Production	Part types that can be produced	Add new technologies

Knoll and Jarvenpaa [17] mapped Evan's [21] typology of flexibility for IT as:

- *Flexibility in functionality (input) – parts ability to withstand variability in input conditions.*
- *Flexibility in use (output) – the ability to recognize opportunities and exploit relationships.*
- *Flexibility in modification (process) – refers to the case and variability of technology modification.*

Mapping the flexibility types on the flexibility categories yields a flexibility framework (Figure 3) for the ASE.

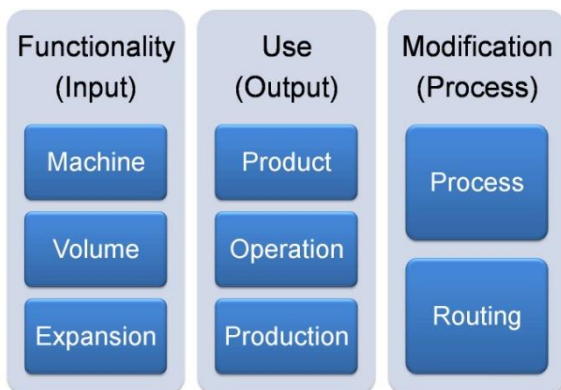


Fig. 3: Flexibility Framework for the ASE

An example of the ASE flexibility framework is if builders place a new tower in the environment, the Flexibility characteristic of the agent would identify characteristics (i.e. height, width, location etc...) and disseminate the information to agents seeking to operate in the environment. The work of Kumar et al [22]

demonstrates how automated guided vehicles using machine and routing flexibility could improve a manufacturing process. This is because the variance of agent communication and functional pragmatics introduces a certain level of mismatch and the need of flexible and adaptive interactions that promote interoperability becomes imperative [23]. Nevertheless, how does the ASE learn what artifacts are either added or deleted from the environment?

B. Intelligence

John Bird of the Underwater Research Lab at Simon Fraser University, writing on how easily autonomous vehicle behavior can be misunderstood for intelligence, notes "Even the definition of intelligence remains a subject of controversy [24]". The Intelligence characteristic is not an element of emotion and self-consciousness. The focus is on the mechanisms and functions as an attribute of the intelligence agent. Intelligence is the capability of discovering knowledge and using it to do something [23]. The Intelligence characteristic of the ASE will gather information from agents as they interact with each other and their environment. According to Sternberg's Triarchic Theory, [25] three aspects of the mind entail intelligence:

- *Analytical/Componential intelligence*
 - o *Traditional notion of intelligence*
 - o *Abstract thinking & logical reasoning*
 - o *Verbal & mathematical skills*
- *Creative/Experiential intelligence*
 - o *Creativity*
 - o *Divergent thinking (generating new ideas)*
 - o *Ability to deal with novel situations*
- *Practical/Contextual intelligence*
 - o *Street smarts*
 - o *Ability to apply knowledge to the real world*
 - o *Ability to shape one's environment; choose an environment*

The ASE will only display Analytical and Practical intelligence. Minsky and Penrose discussed two approaches to designing machines to think. Minsky's approach [26] is to "let us try to understand how humans think and build machines to emulate the processes that produce thoughts and emotions." Penrose's approach: [27] "Let us go down to the cellular and molecular level and try to understand the physics that produces consciousness and understanding." Another researcher Badreddin's [28] bases a structure of intelligence on the assumption that "problem solving capabilities can be constructed from the capability to represent". The following is a list of his structures:

- *Experience - store previous knowledge and reason on it to generate solutions*
- *Innovation - to obtain completely new, unpredictable, solutions*
- *Fusion- to fuse both kinds of solutions to produce the desired problem solution*

- *Learning - to use the obtained solution to update experience. Together, the items, experience, innovation, fusion and learning.*

For example, an agent learns through its sensors that it needs fuel. The Intelligence characteristic of the ASE will provide data to the agent for locating fuel and supply the information to locate the fuel. The agent will then use its processing capabilities to get the fuel. A key capability of the ASE is to identify what information to share with agents to enable decision making in support of the capabilities of the environment.

C. Cognizance

By understanding what the designer deems to be important information, the ASE can make decisions to support test-driven development. The Cognizance characteristic of the ASE models knowledge and awareness beginning when the ASE is aware of agents and entities within the environment. The cognizance characteristics of the ASE could make an agent aware of a fuel source and provide waypoints A-C-D-G because route A-B-C-D is a collision course with another agent. The ASE will need to answer the question of how to make agents aware of each other. The Opera Problem [29] demonstrated how a group of agents could cooperate to get through two rooms divided by a doorway. The investigation used George Mason University's MASON [30] simulation systems to perform the experiment. The problem lies in that the entity currently relies on humans to be its eyes and ears. Sophisticated sensors that detect in unstructured and ambiguous scenarios will allow the ASE to conduct operations with multiple mission scenarios. The ASE will require collaboration characteristics to allow agents to work together to accomplish mission goals.

D. Collaboration

To accomplish the mission goals the ASE will need to use Collaboration. Collaboration explores knowledge sharing, learning, and consensus building. The ASE needs to establish collaboration to accomplish mutual goals and share responsibility. One agent may possess a camera and can be the eyes of sightless agents in the environment. Another agent may have a terrain avoidance capability and can provide terrain following information to other agents. While an individual agent can learn to improve its performance, a society of agents can evolve to find a Pareto optimal configuration for a certain task and environment [31]. Houari et al [32] expanded the BDI model [12] rapport and adaptation forming the RBDIA model. Using rapport, agents could communicate to other agents and collect information. Adaptation is the agent learning from the environment or other agents. The multi agent collaborative system is managed from three perspectives [32]:

- *The subjective world, (how the agent perceives the world) that comprehend the feelings, beliefs, desires, experiences and intentions of the agent*

- *The common social (inter-subjective) world that is embodied the norms, commitments, agent relationships, and institutions to which the agents belong themselves, and which defines how agents stand towards each other.*
- *The objective world of objects and states of affairs (external world) that describes how things are.*

Sarne and Grosz Kraus [33] state, "Agents can benefit sharing information they gather, pooling their individual experiences to improve their estimations of unknown parameters required for reasoning about actions under uncertainty". However, how well these agents perform when given instructions by the environment will depend heavily on their level of Autonomy.

E. Autonomy

Autonomy is characterized by the level of interaction (Table 3) between the vehicle and the human operator: the higher level the operator's decisions are, the more autonomy the vehicle has [34]. Autonomy level 10 is the ability of the intelligent agent to make a choice without any human influence. Developers would test new algorithms incrementally starting with level 1 to test autonomy upon entering the simulation environment until the autonomy level reaches level 5. Scerri and Reed [35] conceptually the task of changing autonomy can be broken into three parts:

- *AA Information (AAI) Collection of the information relevant to the AA decision making*
- *AA Reasoning (AAR) Reasoning about what autonomy changes could or should be made.*
- *AA Actuation (AAA) Realization of the decisions made by the AAR.*

The methods of categorization (AAI, AAR, AAA) will ensure the algorithms are mature enough for multi-agent simulation.

Table 3: Autonomous Control Levels [36]

Autonomy	Level
Remotely piloted vehicle	0
Execute preplanned mission	1
Pre-loaded alternative plans	2
Limited response to real time faults/events	3
Robust response to anticipated faults/events	4
Fault/event adaptive vehicle	5
Real-time multi-vehicle coordination	6
Real-time multi-vehicle cooperation	7
Multi vehicle mission performance optimization	8
Multi vehicle tactical performance optimization	9
Human like	10

F. Artificiality

The Artificiality characteristic will provide the quality of producing events that did not occur naturally. For example, making the agent believe a tower is an obstacle when no tower is present. Putting a Chinese garden in a backyard in California or putting palm trees in a yard in Michigan. Ski slopes have snow machines to create artificial snow when snowfall levels are low. We may one day arrive at a world where climate and weather are actively controlled, where new genetically engineered cultivars and new fauna are common in every landscape, where the human gene pool has entered a period of rapid divergence [37]. The environment and agent considers all artificially phenomena as real. The core idea of artificiality is making the environment capable of providing artifacts that did not occur naturally. The framework to implement the FIC²A² Characteristics of ASE is the next section of the paper.

IV. ASE RECONFIGURABLE ARCHITECTURE

This section outlines the reconfigurable architecture of the ASE for FIC²A² using the Response Ability Principles from agile-systems engineering [15]. The seven guiding frameworks for Response Ability Principles are response requirements categories, response performance metrics, functional design principles, design quality principles, system integrity responsibilities, an overarching architectural philosophy, and a conceptual pattern [38]. Due to the length of this paper, only the functional design principle (drag and drop module) is shown. The drag and drop modules (Table 4) of the ASE system are the components for implementation of FIC²A². The drag and drop modules are; entities, radios, terrain, sensors, data, algorithms, visualization, Human Computer Interface (HCI), and interfaces. These modules are designed in the ASE and are available to ensure rapid configuration.

Table 4: Drag & Drop Modules

Module	Use	Example
Entities	Physical objects used by agents	Aircraft, ships, tanks, trucks, submarines
Radios	Communication between agents	Transmitters and receivers
Terrain	Representation of the earth's surface	DTED, DME,
Sensors	Measure and convert	Locational, EO/IR
Data	Inputs and outputs for system manipulation	Measures of Performance and Effectiveness
Algorithms	Sequence of instructions to manipulate data	Pseudocode and languages
Visualization	Creates images, diagrams, agent monitoring	2-D, 3-D
HCI	Input for agents	Keypads, Keyboards
Interfaces	Connectivity between agents	Routers, software

The entities are the physical objects operating in the ASE employing the intelligent agent technology. Once the entities are employed, the ASE becomes cognizant of the entities and broadcast information about all entities for collaboration. Flexibility results from the capability to task equipment such as cameras and antennas throughout the ASE. The ASE's intelligence of entity capabilities could task an entity with a photographic sensor to take photos. The autonomous nature of the ASE allows the entity to maneuver for the photo and relay the data to the ASE visualization center. Entity considerations include size, weight, power, and resources (air, land, and sea) where the entity will operate. Some examples of resource considerations are proper water depth and clear airspace. The radios are the component for communication and data transfer. Federal Communications Commission (FCC) rules and regulations are examples of radio considerations along with concerns of interoperability, interference, and antenna placement. Terrain elevation data are used for ASE mapping and navigation. Sensors will collect information from the ASE and disseminate the information throughout the ASE. Storage and collection of data is essential for analysis of ASE experiments. How and where data is stored and how the data are retrieved will be the important considerations for designers. Examples of considerations for data include on-site or off-site collection and storage. Algorithms allow designers to provide direction, commands, and functionality for task completion. The flexibility of the ASE allows developers to interject, replace, or upgrade algorithms. ASE visualization techniques will aid in the monitoring of operations within the ASE. Visualization Devices such as card readers, keyboards, and keypads provide The Human Computer Interface (HCI) module. These devices allow developers to input and transfer data to equipment within the ASE. Interfaces are the electronic paths within the ASE and include items such as sensors, radios, and entities. The interfaces allow rapid scenario generation to conduct analysis on multiple scenarios. The difference between HCI and interface modules is the HCI is where human interacts with the ASE while interfaces are where non-human objects within the ASE interact with each other.

Figure 4, provides a graphic representation of the reconfigurable architecture of the ASE. The three components to the architecture are drag and drop modules, integrity management and plug and play rules. The drag-and-drop modules demonstrate the capability to reconfigure to meet customer needs. This agile methodology can be used to conduct simulations such as Optimization, Behavior Formulation, and Concept Formulation. The plug and play nature of the reconfigurable architecture allows for exploration of various model abstraction techniques. Program managers are responsible for the module evolution ensuring the architecture meets changing requirements. Developers and designers manage the module inventory for situational relevance. Testers and evaluators are responsible for the configuration and assemble of scenarios. Finally, managers control the evolution of the infrastructure. Entities also have a stake in the infrastructure due to technological

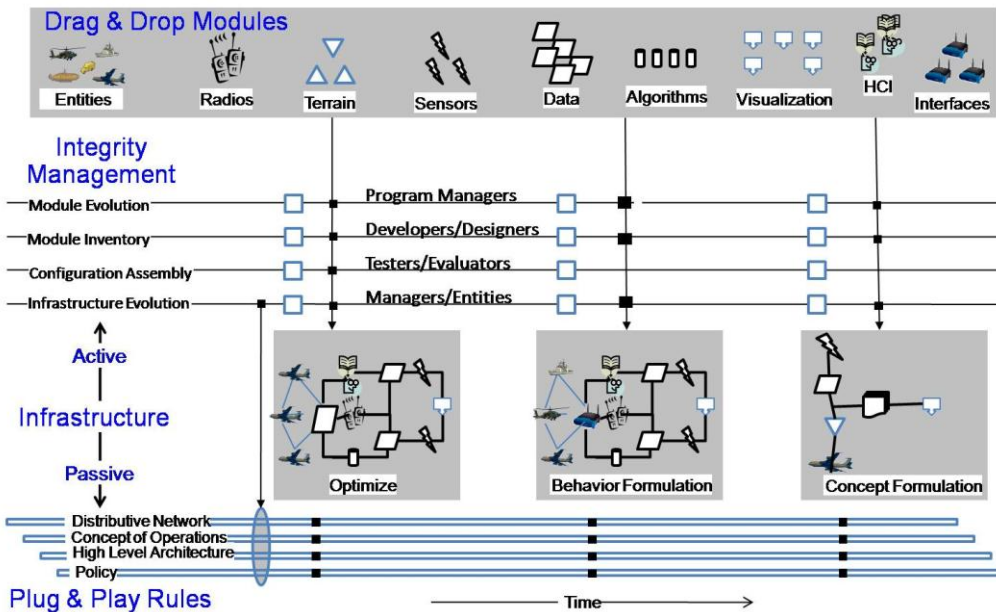


Fig. 4: Reconfigurable ASE Architecture

changes. The plug and play rules are the constraints placed upon the architecture by designers.

To demonstrate the reconfigurable architecture, two scenarios are used for the FIC²A² implementation. In the first scenario (optimize), a developer tests four versions of an intelligent agent to analyze emergent behaviors to select the best option for deployment. The developer tests each version with three entity formations operating together. Each formation has the same physical configuration for the entities. In the second scenario (Behavior Formulation), the developer selects one agent from each of the four versions, in single entity formations, to examine how the agents work together. The goal of the developer in the second scenario is to understand what emergent behaviors the agents will exhibit and how to mitigate those behaviors.

In the first scenario, a developer has a requirement to test four different intelligent agents in a real environment. The goal is to determine which of the intelligent agent has the optimal performance. The agents have undergone laboratory testing and operations in controlled airspace. The developer's customer wants to identify behaviors to expect from the agents in her combat environment when the agents work together. The developer gathers the information (Concept of Operations and Policy documents) and begins to construct the demonstration for four three-group entities to simulate a battle condition. The customer then verifies what the developer has created to determine if the simulation matches the customer's original idea. If needed, the developer makes changes to the simulation visualization on the spot demonstrating the flexible nature of the ASE. The developer uses common interfaces and standards of radios and sensors to communicate between agents and test and evaluation equipment in the ASE. Terrain maps, imagery, algorithms, and flight plans are loaded to the agents through the HCI's to provide cognizance of the environment. Prior to beginning the experiment, the ASE notifies proper organizations of no fly zones, what entities are required, and what artificial objects to inject in the test. The ASE begins the experiment by

transmitting the go ahead and issuing necessary warnings to ASE personnel. The ASE observes autonomous behavior and gathers mission performance data for analysis.

Scenario 2, Behavior Formulation, uses an intelligent agent from each of the four versions in a multi-agent configuration. The difference in this scenario is the developer wants to determine how the agents interact with each other using different physical configurations for each entity. One would expect the behavior to be different because the entities are using different interfaces and standards. Communication

systems can look at different modulation types, frequency ranges, and antenna configurations. Analysts, developers, managers, and evaluators can use the ASE to explore varying configurations and concepts for testing and evaluation characteristics.

V. CONCLUSION

The role of modeling and simulation will only increase and become more and more complex as technology and humans advance and new ways of managing simulation systems are pursued. An Agile environment is necessary if researchers plan to adapt to the ever-increasing advancements in technology. There is no question whether or not intelligent systems will be used in real world situations. The question is will decision makers ever trust them? The objective of this paper is to suggest six characteristics for a fourth ASE system. The ASE system's framework is a platform for examining a systems approach to agile ASE surviving the drag and drop nature of future simulation. Although the typical simulation infrastructure is adequate for built once solutions, multi-agent systems will demand adaptable, highly agile simulation systems to simulate anything they want whenever they want. The FIC²A² characteristics of the ASE require more research to determine a possible relationship into the other five simulation environments of the simulation matrix. Further research is required in the two remaining Simulation Environments: Hardware-in-the-Loop (HIL) as it relates to embedded technologies and to examine Man-in-the-Loop (MIL) as a function of virtual reality. The role of modeling and simulation will only increase as technology and humans advance and new ways of managing simulation systems are pursued.

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