CONSOLIDATED SITUATIONAL AWARENESS FOR AIRCRAFT CARRIER DECISION CENTERS

C2 Decision Making & Cognitive Analysis Track

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ABSTRACT

As the Naval Forces progress toward the network-centric environment envisioned by JV 2010 and JV2020, their dependency upon decision-making aids will grow exponentially as the warfighter's thirst for knowledge from the flood of information rises. As noted from Joint Vision 2020, we "...*must be able to take advantage of superior information converted to superior knowledge to achieve "decision superiority" - better decisions arrived at and implemented faster*....". Particularly of concern are the shortfalls in the consolidated situational awareness available to the decision makers in the Tactical Flag Command Center (TFCCs) and Combat Direction Center (CDCs) onboard aircraft carriers. The existing CDC and TFCC systems do not provide integrated and fused information which requires more people to glean information out of multiple, stove-piped systems. The current systems are not designed to enhance decision-making and information is not presented in an integrated, graphically based manner that facilitates communications and decision support. This increases response times, resulting in reduced mission effectiveness. 21st Century Systems, Inc. is proposing a unique solution to this issue, the Advanced Battlestation with Decision Support System (ABS/DSS) that utilizes an Agent-based Decision Support System coupled with a 2D/3D Battlespace Visualization Tool. The ABS/DSS utilizes 21CSI's Agent Enhanced Decision Guide Environment (AEDGE™) Architecture which expedites generation of Agent-based systems.

1 Introduction

In response to the capability shortfall for consolidated situational awareness in aircraft carrier decision centers, 21CSI is designing, prototyping and will transition a Decision Support System for the Advanced Carrier Battlestation. The Advanced Battlestation with a Decision Support System (ABS/DSS) is a battlespace visualization and decision-aid system that will be used by a battle group commander and his staff who man the decision centers. The ABS/DSS's suite of information management tools prioritize and re-configure the battle picture in real-time to display the tactical information in a manner that is more easily understood and absorbed by combat watchstanders. The development of 21CSI's ABS/DSS is being pursued through a progression of software deliverables: a standalone proof-of-concept mock-up, a detailed prototype, a prototype partially-integrated with other program components' prototypes, a prototype fully integrated distributively, an integrated prototype validated in a Navy testing environment, and finally, an operational insertion of intelligent decision aids into the fleet. The ABS/DSS utilizes 21CSI's Agent Enhanced Decision Guide Environment (AEDGE™) Architecture which expedites generation of Agent-based systems.

In the following, we will first, in section 2, present an overview of the Advanced Battlestation with Decision Support System. In order to more fully present the functionality and capabilities of the ABS/DSS several screen captures of actual running software are used as example illustrations. In section 3, we describe the AEDGE^{TM} architecture and its application in implementing the decision aid model used in the Advanced Battlestation with Decision Support System. We use diagrams and examples to illustrate the coherent relations among the software modules and the functionalities each of the modules will play in terms of their implementation of the mixed strategy. In Section 4, we will briefly discuss the advantages of using the AEDGE architecture in developing systems for complex, interactive, time- and mission-critical decision support systems. Section 5 briefly summarizes the major technique points of the paper.

2 Battlespace Visualization

The current configuration of 21CSI's ABS/DSS allows the watchstander to navigate the 3D battlespace using an attached joystick. Consolidated situational awareness is gained through exploration of the integrated air, ground, maritime, and subsurface environments of the battlespace. Visual cues such as a numeric heading marker, view altitude, and attack angle (located centerline and above the display), whiskey grid lines (engraved into the surface topography), and grid ID markers are used for operator references to facilitate orientation in the 3D environment. Objects in 3D space are represented by standardized Navy AADC icons. The ABS/DSS utilizes Digital Terrain Elevation Data (DTED) and Digital Bathymetric Data (DBDB-V) to provide a 3D terrain for the watchstander to navigate. The operator can select the transparency of the terrain such that a terrain feature will not

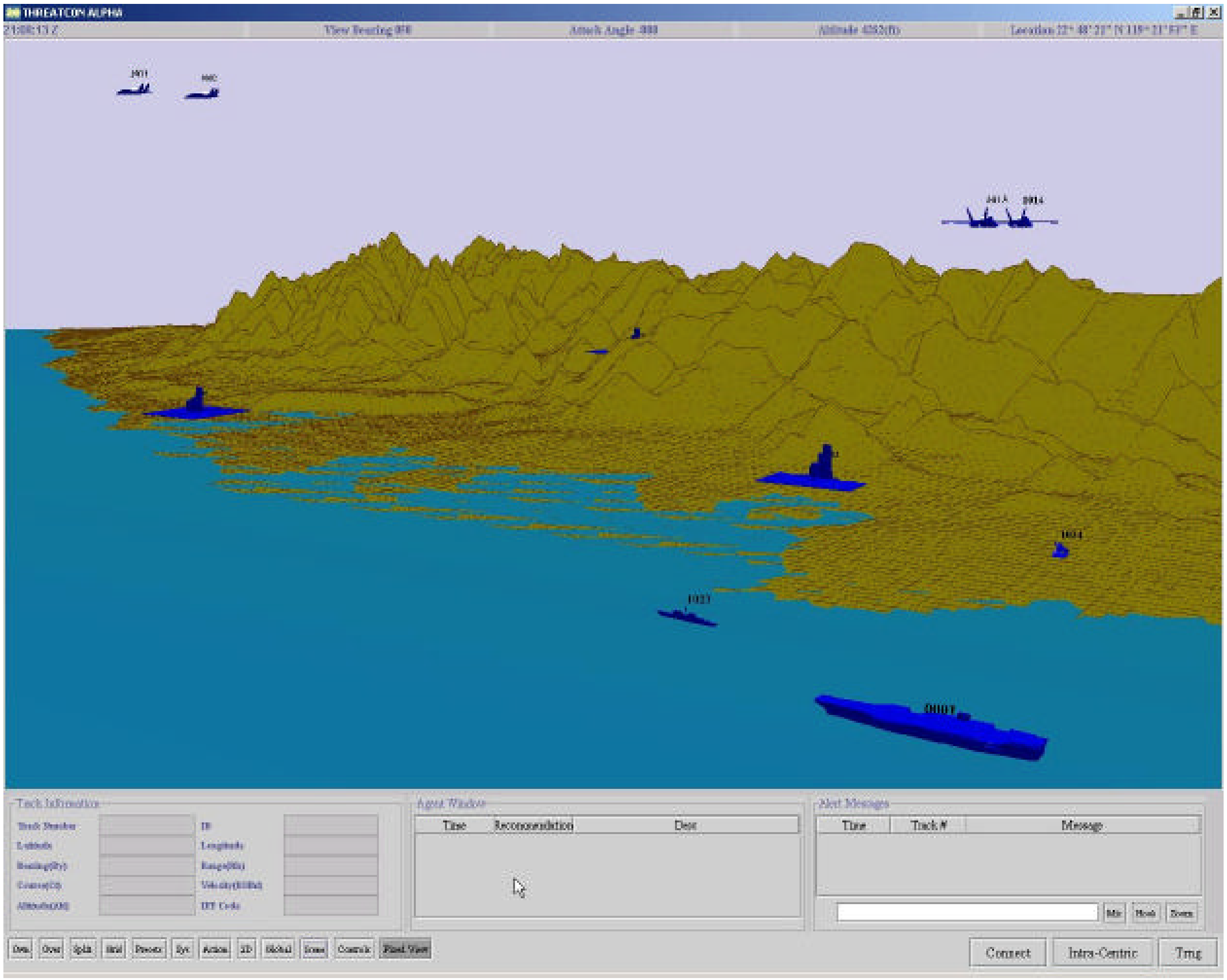


Figure 1. 3D ABS/DSS Display

completely hide the presence of a high interest contact or enemy ground asset. Similarly, the digital bottom contour data is used for the ocean, river, and lake bottom visualizations.

Selecting the "2D" button generates a 2D bird's eye view of the battlespace, shown as the popup window in the upper left hand corner of the 3D display of Figure 2. This 2D map displays contacts using standardized Navy Advanced Combat Direction System (ACDS) icons and the watchstander can selectively change the geographic scale of the 2D map using the zoom function. Observer and object motion in the 2D and 3D space is synchronized. As the watchstander navigates using the joystick in the 3D display, the observer icon (a white circle) moves correspondingly on the 2D display. Additionally, if the watchstander needs to quickly jump from one location in the battlespace to another location some distance away, the watchstander need only to click on that location on the 2D display and both the 2D and 3D visual displays are transported to that location.

A heading leader is included on the observer icon in the 2D map to provide additional visualization cues for the watchstander. The heading leader turns with the observer and corresponds to the heading marker in the 3D map. In other words, navigation in the 2D/3D domains is completely linked with each domain supporting the visualization in the other domain.

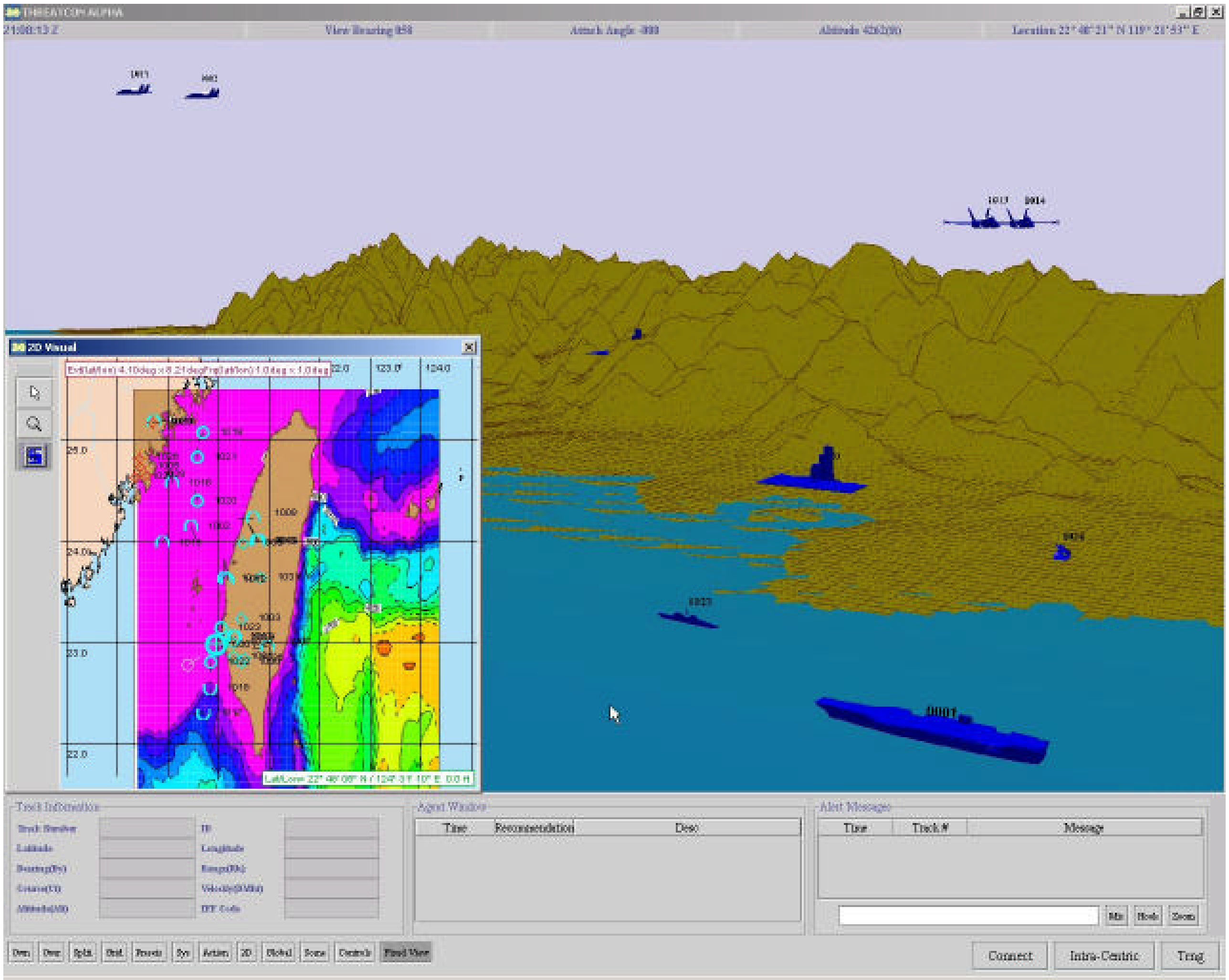
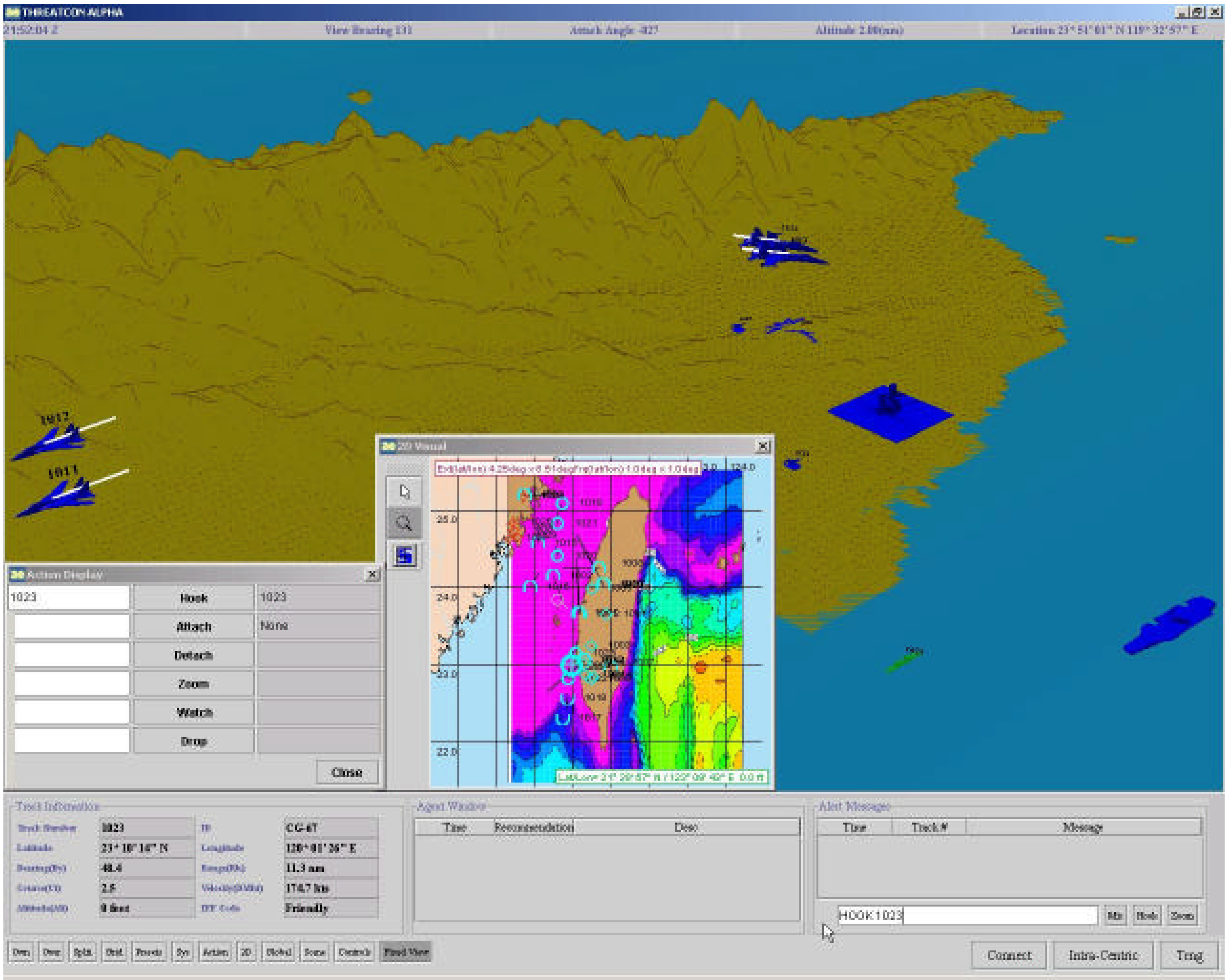


Figure 2. Synchronized 2D/3D ABS/DSS Display

The watchstander has the ability to display information about any known contact in the system. This information is contained in the Track Information Box, shown in the lower left hand corner of Figure 3. The contact's Track number, Identification Friend or Foe (IFF) designator, identification, location (lat/long), bearing, course, speed, range, altitude, are displayed. If information is desired on a contact that is currently in the field of view of the watchstander in the 3D battlespace, the watchstander simply selects the contact using the mouse pointer and the information block will automatically be updated. As shown in Figure 3, the watchstander has selected track 1023, the ship (CG-67) in the lower right of the 3D display. The contact is now highlighted green (friendly) to indicate that this is the contact for which the track information is displayed. If however, the contact is not in the field of view, the watchstander selects the "Action" button and then manual enters the desired contact number in the popup box as shown in Figure 3, in the lower left hand corner of the 3D display. In addition to contacts, the ABS/DSS provides for the capability to select all fixed or mobile ground assets. The information about these ground assets is displayed similar to the procedure described for contacts.



Action Display

1023	Hook	1023
	Attach	None
	Detach	
	Zoom	
	Watch	
	Drop	

Track Information

Track Number	1023	ID	CG-67
Latitude	23° 10' 14" N	Longitude	120° 01' 26" E
Bearing(Brg)	48.4	Range(Rng)	11.3 nm
Course(Crs)	2.5	Velocity(SMth)	174.7 kts
Altitude(Alt)	0 feet	IFF Code	Friendly

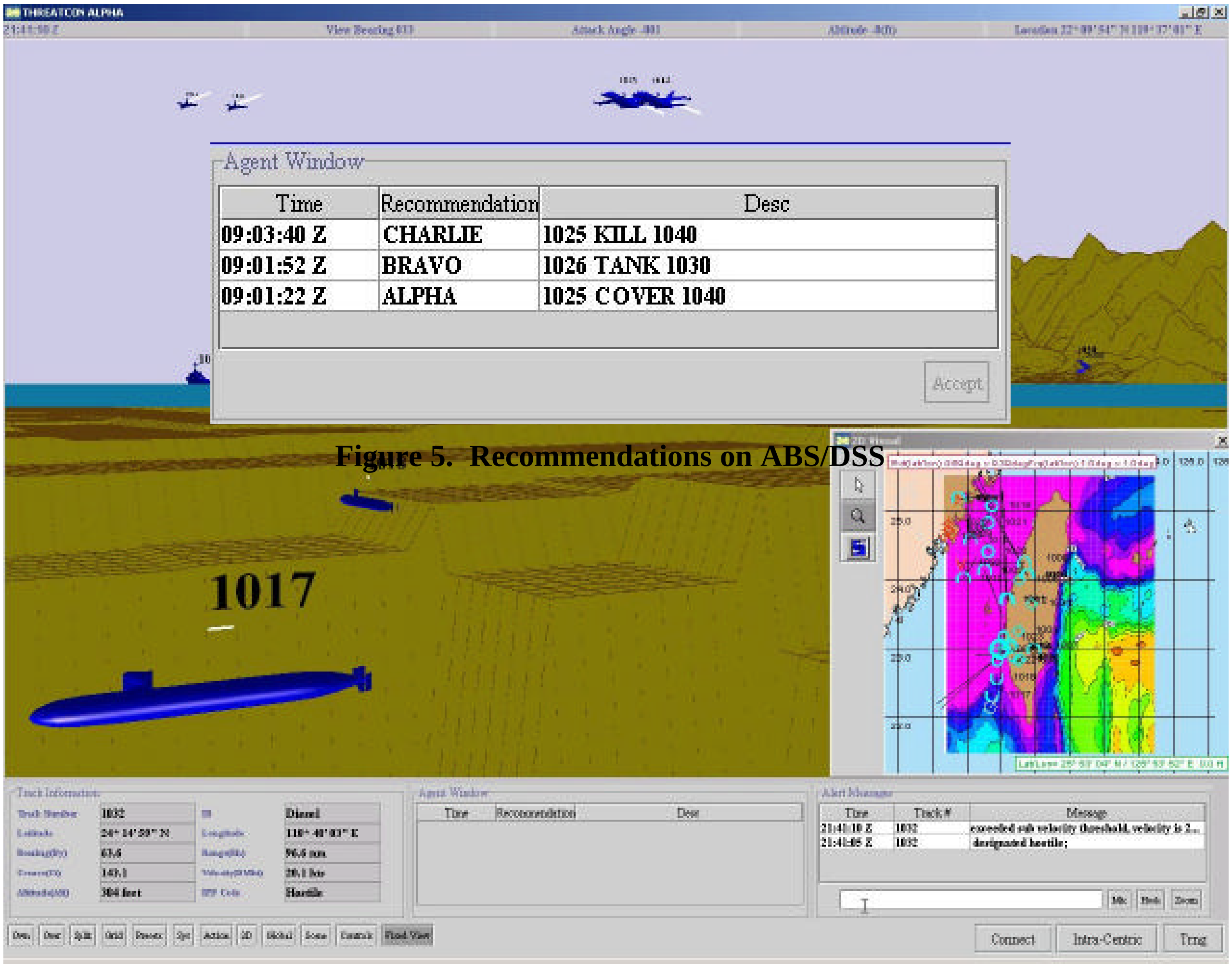
HOOK 1023

Figure 3. Hooking Contact for Track Information, ABS/DSS

In the current configuration of 21CSI's ABS/DSS, rudimentary agent technology is employed in order to facilitate the watchstander's situational awareness. Agents notify the watchstander of contacts that violate tripwires. The tripwire values are operator selectable by selecting the "Alert Presets" button and using the appropriate password. Adjustable tripwires for contacts include but are not limited to:

Minimum or Maximum Airborne Speed
Minimum Airborne Range
Minimum or Maximum Airborne Altitude
Minimum or Maximum Surface Speed
Minimum Surface Range
Minimum or Maximum Submerged Speed
Minimum Submerged Range
Threat IFF
Contact Weapon Range
Initial Detection of Hostile Contacts

The agents utilized by the DSS analyze all known contacts against the Alert Presets and displays a message in the Alert Message Box if a tripwire is violated. The displayed message indicates the time of the alert, the contact number, and the tripwire exceeded as shown in the lower right hand corner of Figure 4. In this case, at 2141:10Z a new hostile contact, designated track 1032 is reported. The Alert Message Box, in its normal configuration operates as a waterfall display with the most recent alert appearing at the top. If the watchstander desires to sort the alerts, he may sort the alerts in ascending or descending chronological order and/or by contact number.



Agent Window

Time	Recommendation	Desc
09:03:40 Z	CHARLIE	1025 KILL 1040
09:01:52 Z	BRAVO	1026 TANK 1030
09:01:22 Z	ALPHA	1025 COVER 1040

Figure 5. Recommendations on ABS/DSS

Track Information

Track Number	1032	ID	Diesel
Latitude	24° 14' 59" N	Longitude	118° 40' 03" E
Bearing	63.6	Range	96.6 nm
Course	143.1	Velocity	20.1 kts
Altitude	304 feet	IFF Code	Hostile

Alert Messages

Time	Track #	Message
21:41:10 Z	1032	exceeded sub velocity threshold, velocity is 2...
21:41:05 Z	1032	designated hostile;

Figure 4. Alert Messages on the ABS/DSS

The ABS/DSS is supported by 21CSI implemented COTS voice synthesis and recognition software that allows the watchstander more freedom in performing his duties in a less distracted, hands-free environment. Using Text-to-Speech voice synthesis, 21CSI's ABS/DSS utilizes a computer-generated voice to deliver aural alert notifications to the watchstander's headset or external speakers. Abbreviated voice notifications are provided to lessen the distraction of the watchstander by alerting the watchstander of an alert instead of watchstander having to inefficiently check the Alert Message Box continuously for new alerts. If the abbreviated voice notification stimulates a need for further information about the alert, the watchstander has an archived list of the alerts in the Alert Message Box to review. For voice recognition, 21CSI's ABS/DSS uses grammatical rule sets to implement system control functions to facilitate operation in a hands-free environment. For example, the watchstander simply speaks into the headset to "Hook Contact Number XX" or "Zoom Contact Number XX." The verbal commands provide an alternative hands free operating mode for the respective manual button operations described above.

21CSI's ABS/DSS utilizes agents to analyze the battlespace to provide recommendations to the watchstander concerning the tactical situation. The ABS/DSS lists the recommendations in the Agent

Window located in the lower center of the 3D display. Additionally, 21CSI’s ABS/DSS provides audible notification of the recommendations via the voice synthesis software. Recommendations are specific to the particular warfighting specialty that the watchstander is responsible for at the respective station. In the case shown in Figure 5, the agent recommended “1025 COVER 1040” just after track 1040 took off from an unfriendly airstrip (1025 is a friendly fighter). As the situation progresses, the tactical picture changed when track 1021, a helicopter, is endangered. The rules of engagement have changed and the agent recommends “1025 KILL 1040.” Similarly, Figure 5 shows a recommendation for refueling the friendly fighter 1026. 21CSI’s ABS/DSS provides recommendations only and the human-in-the-loop can choose to accept the recommendation and issue the order to 1025 or ignore the recommendation if other considerations not available to the ABS/DSS must be incorporated into the decision.

3 Software Architecture - AEDGE™

21CSI’s extensible multi-component Decision Support Systems (DSS) architecture, known as AEDGE™, is a standardized COTS, DII COE compliant agent architecture that enables complex DSS to be developed as an expansion of the AEDGE™ core functionality. The need for a standardized common infrastructure has led us to design an environment where both agents and real/simulated entities (or representations of real-world assets) are represented as first-class objects capable of interacting with each other. The AEDGE™ is 21CSI’s undertaking to build a common reference framework and a test-bed environment for integrated simulation and agent-based decision support. The architecture describes the data objects, interfaces, communication mechanisms, component interactions, and integration mechanisms for the AEDGE™ and its extensions. The ABS/DSS is an extension of the AEDGE™. In this section we will introduce the AEDGE Architecture and in section 4 the advantages of using the AEDGE will be briefly discussed.

3.1 AEDGE Information Flow

The AEDGE Information Layer provides data format definitions (data Objects) and information flow descriptions shown in Figure 6. As part of the AEDGE infrastructure, four major packages of data Classes are defined. These classes form the base AEDGE information environment, which supports persistent and remote data access through serializable data.

Geographic and Terrain Data. These define locations, routes, and geographic areas, with their coordinates, elevations, and properties. For example, terrain properties (elevation, soil type, vegetation, etc.) are stored in TerrainData objects. Coordinates and locations are encoded by Location objects, which also define unique names for the locations.

Entity and Track Data. This hierarchical set of classes defines the data objects associated with track information. Entities are characterized with their speed, heading, fuel status, and so on. Targets carry priority and classification data, while Platforms contain information about the weapons and sensors carried onboard.

Agent Data. While Agents are mostly functional entities and not typically data-heavy objects, some Agents may choose to preserve some or all of their data in a serializable (or persistent) format. Such

Agents will be able to store and modify their characteristics as well as possess the ability to migrate among network nodes.

Metrics and Measures Data. As part of the AEDGE information infrastructure, performance, scoring and other measures and metrics are supported. The Metrics and Measures package defines the data classes for storing and exchange of metrics data. These include Trainee Scores, Communication Measures, Load Measures, Interaction Measures, and so forth.

Data-Bridge Interfaces. Though not part of the Information Layer, the data bridges are essential components of the AEDGE infrastructure as they provide connectivity to external, components, and information sources. External information sources, such as DIS/HLA compliant simulators, Sensor Feeds, Standard Databases, instrumentation and monitoring and visualization tools, etc. can be connected and interact with the AEDGE through a variety of data bridges.

3.2 AEDGE Components and Services

21CSI's AEDGE components are the base software units providing various functionalities to the user and to other components. Figure 7 shows these base units. Infrastructure Components are components that provide connectivity and manage other components. All Functional Components encode algorithms for various types of processing. Components communicate to each other by sending Service Requests (using the Service object to store the request data) and receiving Service Results. When a given component needs to send a message to the "clients" or Service Requestors subscribed to it, simple Message object is used for efficiency. The message can advertise service availability at the sender component or it may provide a one-time notification or information item.

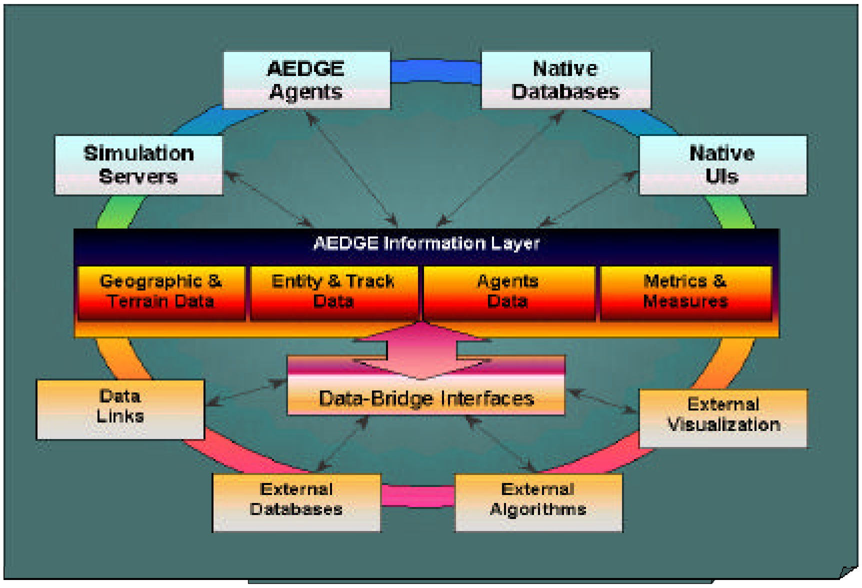


Figure 7. AEDGE base components and services

Figure 6 AEDGE Information Flow

3.2.1 Component Interactions

In the AEDGE architecture, components communicate among each other via the Service Provider/Service Requester Protocol (SPSR). Service providers are components that implement an algorithm or need to share their data (data sources). Service requesters are the components that need a function performed for them by some other component or need to import data from another component. Both service requesters and service providers implement remote interfaces, which enables such components to communicate over a TCP/IP network. The remote interface implementation is currently based on Java RMI (remote method invocation, a type of simplified ORB service), though the Architecture is not dependent on this implementation.

The SPSR protocol is based on three data objects: Service, ServiceResult and Message. The Service object encapsulates the class, the type, the required quality of service (QoS) and the parameters of a service request. The ServiceResult object provides a reference to the original service, a return code (success or failure), a return object (String, Recommendation, etc), and an actual received QoS. Messages provide a way of service providers to advertise the availability of new services and to notify subscribers of new data available.

Service provider components register their location and the services they provide with a Component Registry, which is responsible for tracking and maintaining service provider information current. Service requesters lookup service provider information from the Component Registry and then establish a direct connection with the providers they wish to engage. A service request (either blocking or non-blocking) is sent from the service requestor to the service provider. The provider then replies (immediately or at some future time with a ServiceResult.

3.2.2 Agents and Agent Interactions

Agents in AEDGE are specialized components that generate recommendations either in response to a user inquiry or spontaneously, according to their function. Agents are usually organized in agent communities, unified under an Agent Manager component, which is responsible for invoking and synchronizing individual agents.

The Agent Manager interacts with agents via the SPSR protocol, while users (through UIs) interact with the Agent Manager through more user-friendly Inquiry/Recommendation exchange protocol (IREP). The users can query the agent manager by sending context information (entities, geo-references, target information, etc.) and specific requests for recommendations. The query is internally translated to service requests and sent to the Agent Manager. The users are not limited to the IREP – they can use any query representation, such as SQL queries, as long as they can be internally converted to service requests.

Upon receiving a user-level query, the Agent Manager selects and invokes the appropriate agents to perform the desired tasks. The Agent Manager has a table of registered Agents and their capabilities. Thus, the Agent Manager is the one that partitions the problem, sends sub-tasks to the individual Agents, and later combines and deconflicts the solutions. After an overall solution is reached, the Agent Manager forms a set of recommendations, which are returned to the User via a ServiceResult object. In essence the IREP is a user-friendly protocol build on top of the SPSR protocol.

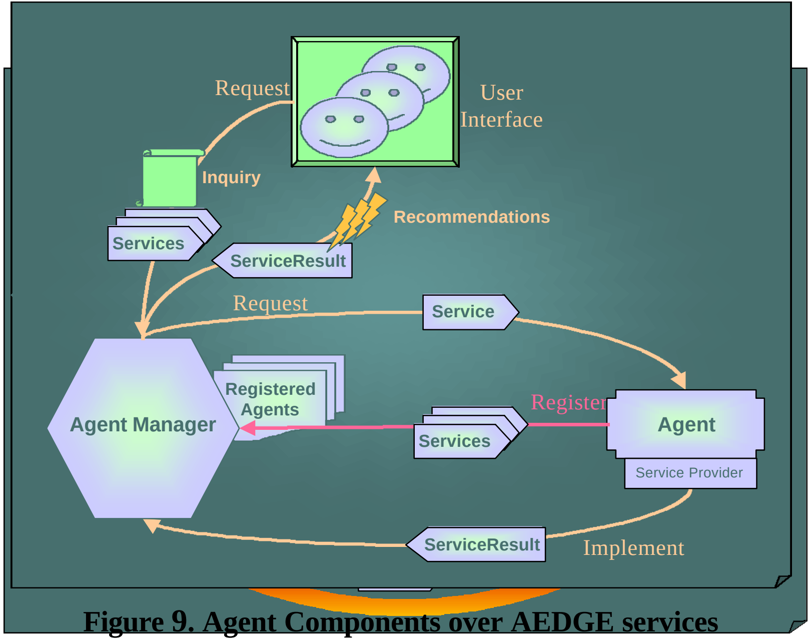


Figure 9. Agent Components over AEDGE services

Figure 8. AEDGE SPSR protocol interactions

The interactions among agents and the Agent Manager are solely based on the SPSR protocol, as these are optimized for efficiency and not necessarily for user-friendliness. Figure 10 demonstrates four different modes of User/Agent-Manager/Agent interactions, described below.

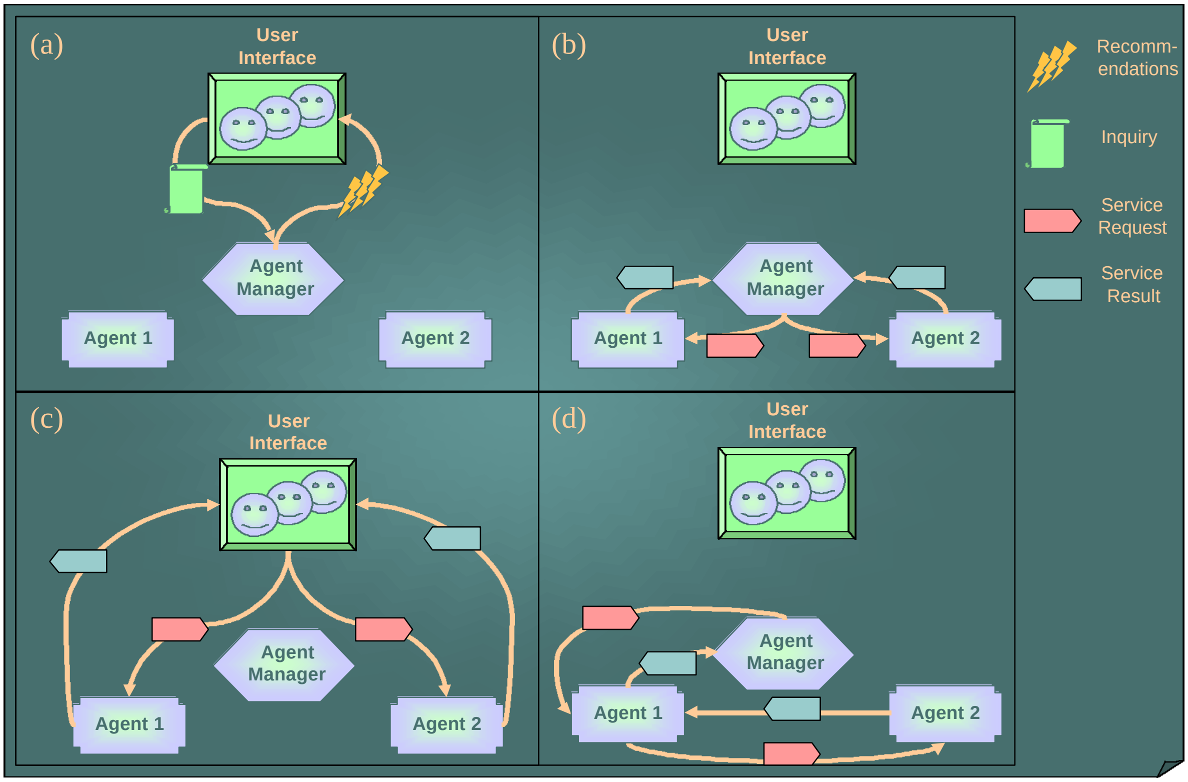


Figure 10. Different modes of agent interactions: (a) User to Agent Manager; (b) Agent Manager

a) **User to Agent Manager Interactions**. Essentially the user sends an inquiry to the Agent Manager, based on the user's current needs and query representation language. The inquiry may consist of a task description and optionally a context update, such as platforms, targets, geo-references etc. The inquiry is internally serialized and translated into service requests, which are then sent to the Agent Manager via the SPSR protocol. After the Agent Manager performs the requested tasks, it sends a reply in the form of a set of recommendations. Recommendations are core objects in AEDGE's framework, which represent desired actions and commands. Recommendations may be produced by both Agent Managers and users and are interpreted by Entities to form tasks and orders. In this case Recommendations are generated by the Agent Manager and sent for approval to the User.

b) **Agent Manager to Individual Agents**. In this interaction the Agent Manager partitions the task to subtasks for the individual agents, registered under the Manager. Subtasks are then sent to the agents via the SPSR protocol, encapsulated in Service objects. After the individual agents arrive at a solution they respond to the Agent Manager with ServiceResult objects, which are interpreted by the Manager. The Agent manager performs synchronization and deconfliction of the individual agents' results to ensure that the user will receive a coherent set of recommendations (in case individual agents had provided conflicting information).

c) **User bypasses Agent Manager**. The user can interface directly with the individual agents, using the SPSR protocol. If the user process can locate the Service Provider of an agent (via a Component Manager where that agent is registered), the user can send service requests directly to the agent and listen for the ServiceResult object in the reply. This places the burden of locating and interfacing with the agent's service provider on the user, but it provides more flexibility and faster response.

d) **Agent-Direct interaction**. Agents can communicate with each other indirectly (through the Agent Manager) or directly, via the SPSR protocol. The Requester agent looks up other agents' service providers from any component manager (including the Agent Manager) and can then send service requests to other individual agents. The Provider Agent handles the service request just like it would handle a request from the Agent Manager. The Requester agent needs to be able to handle the ServiceResult returned by the Provider. Agent-direct interaction provides the flexibility of extending the agent community that belongs to an Agent Manager without having to modify the login of the Manager itself.

4 Benefits of the AEDGE^{TM} Architecture

21st Century Systems, Inc.'s AEDGE provides a common framework, information exchange mechanisms, and standard libraries of agent algorithms. The AEDGE kernel is extended by a family of components, which provide users with customized decision support toolkits. AEDGE has an open architecture, capable of connecting to any data source as well as exporting data to any well-defined format.

AEDGE provides multiple levels of customization. The AEDGE-based Scenario Editor can automatically generate user-built scenarios and scripts. Rules and triggers for agent behaviors can be created and modified by the advanced user. AEDGE also provides APIs for custom extensions of agents, data bridges, and the COP framework. The sophisticated user will be able to use AEDGE as a flexible development and testing environment for DSS components. The practical user will enjoy AEDGE's versatile data connectivity and its near-real-time execution and monitoring of DSS functions. As a built-in bonus, AEDGE provides connections to a number of simulators and data formats, including HLA, DIS, DTED, DBDB2, XML, as well as support for multiple modes of distribution (CORBA, RMI, TCP/IP).

5 Conclusion

This project explores the problem of providing consolidated situational awareness to aircraft carrier decision centers by fielding an Agent-based decision support system coupled with a 2D/3D linked battlespace visualization tool. 21CSI has chosen to implement the system utilizing 21CSI's Agent Enhanced Decision Guide Environment (AEDGE™). The effort has been extremely successful in the rapid development, and prototyping of the system and initial shore-based testing has been very encouraging. The ABS/DSS is ready for code production and extensive at-sea testing.

6 Acknowledgements

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