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The Augmented REality Sandtable (ARES)

by Charles R Amburn, Nathan L Vey, Michael W Boyce, and MAJ Jerry R Mize

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by Charles R Amburn, Nathan L Vey, and MAJ Jerry R Mize
Human Research and Engineering Directorate, ARL

Michael W Boyce
Oak Ridge Associated Universities, Oak Ridge, TN

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14. ABSTRACT

The Augmented REality Sandtable (ARES) is a research testbed that uses commercial off-the-shelf products to create a low-cost method of geospatial terrain visualization with a tangible user interface which can be used for simulation and training. The projection technology combined with a Microsoft Kinect sensor and a laptop is intended to provide an enhancement to traditional military sand tables. This report discusses the development of the system, its place among previous related work, and research methodology/experimentation efforts to assess impacts on human performance. It also provides an explanation of current, ongoing, and future research questions and capabilities. It discusses current collaborations and key leader engagements up to this point. The goal of this report is to provide a resource for researchers and potential collaborators to learn more about ARES and the opportunity to use its service-oriented architecture for the development of content for specific domains.

15. SUBJECT TERMS

augmented reality, military sand tables, simulation, training, tangible user interface

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1. Introduction

The US Army Research Laboratory (ARL) Human Sciences Campaign calls out the topic of Virtual/Mixed and Augmented Reality as one of the research aims of 2015–2035. The goal is to use human-machine interaction to support training (Army Research Laboratory 2014). Augmented reality (AR) is a type of virtual environment. In virtual reality (VR), the totality of the environment is computer generated. In AR, the real world is augmented by virtual objects or entities (Milgram and Kishino 1994; Azuma 1997). AR adds to the real world environment, where VR replaces that environment. The Augmented REality Sandtable (ARES) is uniquely situated to address this goal using inexpensive, readily available commercial technology. ARES is a research project being conducted at the ARL Human Research and Engineering Directorate (HRED) Simulation and Training Technology Center (STTC) that combines a traditional military sand table with a Microsoft Kinect sensor to enable new possibilities for terrain visualization and learning via a tangible user interface (Ishii and Ullmer 1997; Ratti et al. 2004).

2. Definition of the Problem

Sand table exercises (STEXs) are historically recognized as an effective means to conduct tactical training with an emphasis on cognitive skill development and tactical decision making (Cohen et al. 1998; Wildland Fire Lessons Learned Center 2011). The ARES research testbed seeks to maintain the positive tangible attributes of the traditional sand table with the benefits of the latest in commercial off-the-shelf (COTS) digital technologies. One area of research for ARES is the tangibility aspects of simulation, also known as tangible user interfaces (TUIs). TUIs are interfaces in which digital information can be manipulated using physical objects in the world, such as your hand or a stylus (Ishii and Ullmer 1997); users have the capability to physically interact with the device through touch. This report discusses some of the existing research within the scope of TUIs and how they relate to the technology of ARES.

The desired end state is an augmented sand table platform that supports a variety of research, training, and operational needs. In recent years, several high-tech alternatives to the traditional sand table have been proposed, such as multitouch surfaces (Bortolaso et al. 2014), 3-dimensional (3-D) holographic displays (McIntire et al. 2014), and immersive virtual environments (Qi et al. 2005). However, the costs associated with developing, fielding, and sustaining such systems are excessive, especially when compared to the cost of a traditional sand table. This cost has limited the adoption of these modern technologies (Sutton 2004).

3. ARES Components

The ARES proof-of-concept table is a traditional sand table filled with play sand and supplemented with low-cost COTS components, which are shown in Fig. 1. They include the following equipment:

- A commercial projector (~$900)
- Microsoft's Kinect sensor (~$200)
- A COTS laptop (~$3,000)
- An LCD monitor (~$400)
- Government-owned ARES software
- An optional web camera (~$100)

Fig. 1 ARES components

The Kinect sensor scans the surface of the sand and detects user gestures above the sand (Fig. 2). Then ARES software creates a map of the sand topography and provides that to client applications. This allows ARES to dynamically respond to the changing shape of the sand based on user interaction and hand gestures.

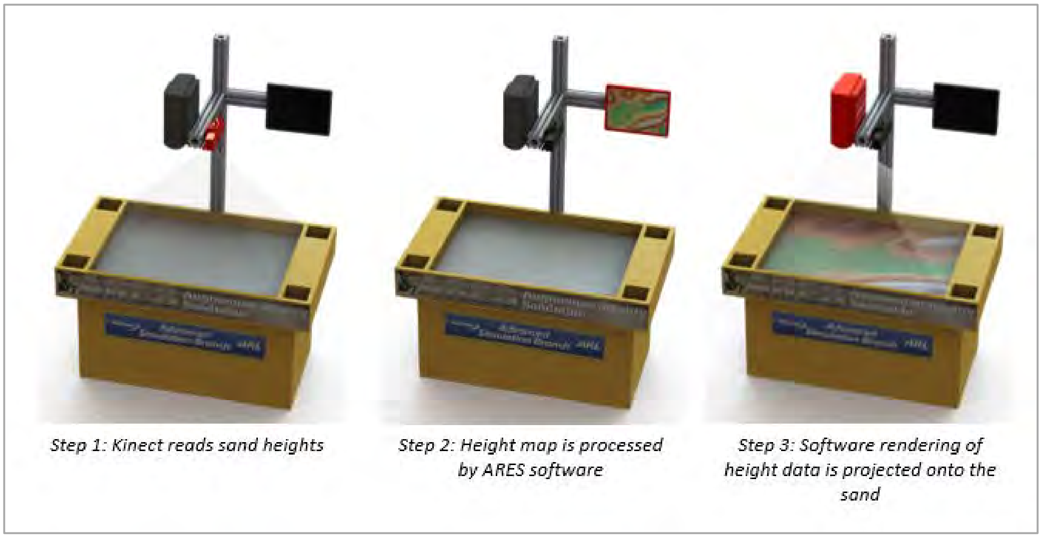

Fig. 2 Terrain recognition process

4. Potential Research Payoffs

This technology may provide a significant return on investment in many areas:

- Improved spatial awareness, battlespace visualization, and the development of a common operational picture
- Increased engagement, retention, and collaboration among students and operational Warfighters
- Decreased time to author virtual and constructive 3-D terrains and scenarios
- Joint/coalition wargaming and mission planning through networked ARES tables

5. Relevance to the Army

With an investment into its continued research and development, ARES will support an array of Army requirements. Army Warfighter Outcomes (Army Capabilities Integration Center 2012) applicable to ARES include the items listed in Fig. 3.

Fig. 3 Army Warfighter Outcomes supported by ARES (Army Capabilities Integration Center 2012)

6. Related Research

There are related past research efforts to ARES in academia, industry, and government. Table 1 provides a comparison between related past research and ARES.

Table 1 Past research related to ARES

First author (year)	Title	Type of interface	Projection	Tangible user interface	Low cost	Human subjects testing
Kirby (1995)	NPSNET: Software Requirements for Implementation of a Sand Table in the Virtual Environment	Completely virtual interface using Modular Semi-Automated Forces	No	No	Unknown	No
Vaglia (1997)	The Virtual Sand Table	Uses a Stylus and Voice Recognition to interact with interface	Yes	No	Unknown	No
Alexander (2000)	Visualisation of Geographic Data in Virtual Environments	Projection, Semi-Immersive Display with some interactivity	Yes	No	Unknown	Pilot Testing
McGee (2001)	Creating Tangible Interfaces by Augmenting Physical Objects with Multimodal Language	Uses voice and pen recognition as well as token placement to support map based planning	Yes	Yes	Unknown	Yes

Table 1 Past research related to ARES (continued)

First author (year)	Title	Type of interface	Projection	Tangible user interface	Low cost	Human subjects testing
Wisher (2001)	The Virtual Sand Table: Intelligent Tutoring for Field Artillery Training	Computer-based tutoring system with 2-D and 3-D perspective views	No	No	Unknown	Yes
Ishii (2002, 2004)	Bringing Clay and Sand into Digital Design — Continuous Tangible User Interfaces	Projection sand / clay-based tangible user interface	Yes	Yes	Depends on System	Yes
Reitmayr (2005)	Localisation and Interaction for Augmented Maps	Projection-based map augmentation using a Personal Digital Assistant (PDA) as an interaction device	Yes	Yes	Unknown	No
Kobayashi (2006)	Collaborative Simulation Interface for Planning Disaster Measures	Projection-based tabletop with manipulators	Yes	Yes	Unknown	Pilot Testing
Couture (2008)	GeoTUI: A Tangible User Interface for Geoscience	Projection-based tabletop with multiple manipulators	Yes	Yes	Unknown	Yes
Jung (2008)	Virtual Tactical Map with Tangible Augmented Reality Interface	Tactical map with browser and manipulators / tangible markers	Yes	Yes	Unknown	No
Kalphat (2009)	Tactical Holograms in Support of Mission Planning and Training	Tested terrain holographic images with Soldiers to support missions	Yes	No	No	Yes
Hilliges (2009)	Interactions in the Air: Adding Further Depth to Interactive Tabletops	Uses sensors and rear projection to allow for manipulation above the tabletop	Yes	No	No	No
Haihan (2010)	Research on the Technology of Electronic Sand Table Based on GIS	Virtual environment sand table	No	No	No	No
Martedi (2010)	Foldable Augmented Maps	Using a Head-Mounted Display (HMD) and maps with intersection dots; maps can be folded and still use augmented display	No	Yes	No	Yes

Table 1 Past research related to ARES (continued)

First author (year)	Title	Type of interface	Projection	Tangible user interface	Low cost	Human subjects testing
Tateosian (2010)	TanGeoMS: Tangible Geospatial Modeling System	Tangible geospatial modeling system which uses a laser scanner	Yes	Yes	No	No
Schneider (2011)	Benefits of a Tangible Interface for Collaborative Learning and Interaction	Projection-based tangible user interface to determine object layout	Yes	Yes	Unknown	Yes
Zhang (2011)	AR Sand Table with VSTAR System	Augmented Reality Sand table with viewer and an attached camera	No	No	No	No
Harshitha (2013)	HCI Using Hand Gesture Recognition for Digital Sand Model	Uses projections, mirrors, cameras and terrain with gesture control	Yes	Yes	Unknown	No
Schneider (2013)	Preparing for Future Learning with a Tangible User Interface: The Case of Neuroscience	Underneath Tabletop Projection, Tangible User Interface	Yes	Yes	Unknown	Yes
Bortolaso (2014)	Design of a Multi-Touch Tabletop for Simulation-Based Training	Tabletop Command and Control Tangible User Interface	No	Yes	No	Yes
Jianping (2014)	An Application Development Environment for Collaborative Training Sand Table	Multi touch tabletop for ecommerce	No	Yes	No	No
Petrasova (2014)	GIS-Based Environmental Modeling with Tangible Interaction and Dynamic Visualization	Follow-up to Tateosian (2010): Tangible interface using Kinect and sand to form terrains	Yes	Yes	Yes	No
Xiaofeng (2014)	Making a Virtual Sand Table Based on Unity 3D Technique	Full Virtual Environment	No	No	Unknown	No
Zhao (2014)	Research and Design on Power SUPPLY NETWORK Sand Table Exercise System	Virtual Display with Elevation Maps for Power Grids using sand table principles	No	No	Unknown	No
Ma (2015)	Using a Tangible Versus a Multi-touch Graphical User Interface to Support Data Exploration at a Museum Exhibit	Tabletop Tangible User Interface with Manipulators	No	Yes	No	Yes

7. ARES Current Demonstration Capabilities

ARES currently has the following capabilities:

- **Projection of Images, Maps, and Video From Any Source onto the Sand**
  ARES can be logged into a VBS3 (Virtual Battlespace 3) or OneSAF (One Semi-Automated Forces) scenario, for example, and display a top-down "instructor's view" of the scenario in real time.

- **Export of the User-Shaped Sand as a 3-D Terrain File**
  Created terrains (and potentially, scenarios) can be imported into a variety of simulation applications, such as VBS3 or OneSAF.

- **Placement and Labeling of Units**
  A subset of Military Standard (MIL-STD) 2525C military symbols and icons and tactical graphics can be created, labeled, and placed for mission planning; these plans ("scenarios") can then be saved for later reuse (Fig. 4).

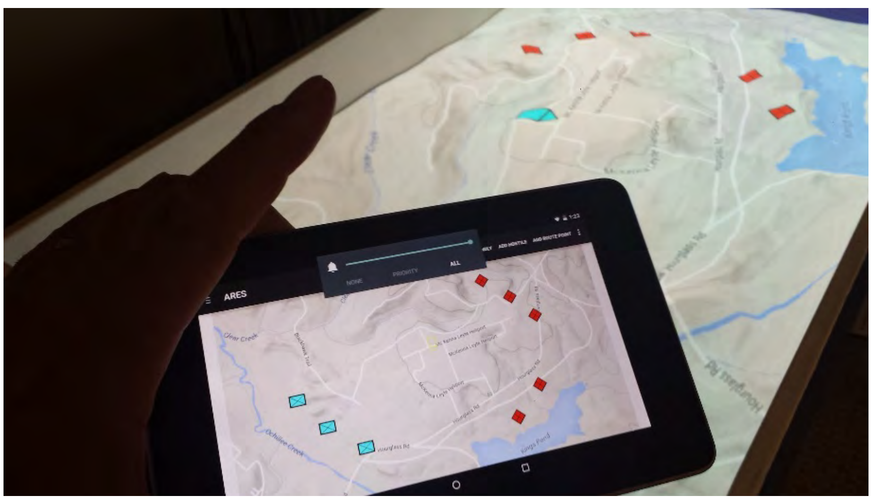

Fig. 4 Using a tablet to place units on ARES

- **Assisted Terrain Correlation**
  Through visual aids (e.g., color schemes and contour lines), ARES provides users with basic guidance in shaping the sand to match a previously saved 3-D terrain.

- **Universal Serial Bus Human Interface Device**
  Capability for ARES to be viewed as a standard interface device (like a mouse or keyboard) so that users can plug ARES into a simulation and use hand tracking to navigate menus as if their hand were the mouse.

- **Hand/Gesture Tracking**
  Detects and tracks the presence of a hand, or hands, above the sand and allows for software responses to be linked to where a user points.

- **Video Teleconference**
  An inexpensive commercial web camera and integrated software allow distributed users to communicate and collaborate in real time. Through the use of the integrated color camera on the Kinect sensor, users are also provided a top-down view of the collaborator's table.

- **Augmented Reality (AR) Peripherals**
  Layers of data can be displayed through AR goggles or AR apps on a tablet. For example, with collaboration from Marine Corps Systems Command, helicopters that hover and fly routes above the sand have been demonstrated as an early concept. When the Soldier Training Enhancement Package (STEP) 3-D, another STTC research project, is incorporated, 3-D buildings and vehicles pop up from the terrain (Fig. 5).

Fig. 5 Augmented reality vehicles and buildings on ARES

- **Contour Lines**
  The system can display terrain features and hypsometric displays (terrain contour lines) to mimic topographic maps.

- **Line of Sight (LOS)**
  The system allows for the dynamic display of a selected unit's LOS either based on the sand's topology or on synthetic environment data provided in the Layered Terrain Format (LTF).

8. ARES Ongoing Research and Development

The following ARES research and development efforts are ongoing:

- **Effects of Different Mediums**
  Other mediums (e.g., different types of sand, clay, magnets, 3-D printed relief maps) offer different benefits, such as the ability to represent vertical surfaces. The effects of using these alternatives (realism, accuracy, immersion) are being investigated to understand how the selection of medium changes human performance factors.

- **Expansion of Unit Libraries**
  More of the MIL-STD-2525C unit iconography is being incorporated to support wider applications.

- **Shared Table States**
  Networked tables will be able to share/compare topography data and unit placement to support distributed collaboration (training, planning, operational support) across the room or across the globe.

- **Rapid Authoring of Training Content**
  Analysis and design of a user interface allowing end users to create their own instructional content on ARES, including the ability for learners to answer questions naturally by pointing to locations or units on the sand.

- **Operational Unit Research and Evaluation**
  Coordination has begun to conduct experiments on usability, effectiveness, transfer, and operational impact with operational military units, such as the 3rd Infantry Division at Ft. Benning.

- **Assisted Terrain Correlation**
  The existing base functionality will be examined for enhancements to speed and usability.

- **Publishing of Architecture**
  The ARES architecture and Application Programing Interface are being published for community feedback and development of end-user applications.

- **ARES' Relationship to Affect/Engagement**
  Research is planned to assess the affective change caused by the interaction with ARES.

- **Sample Application: Tank Combat Game**
  A simple tank combat game (Fig. 6) is being developed to evaluate, demonstrate, and document the capability for end users to easily develop their own custom apps that leverage the ARES platform.

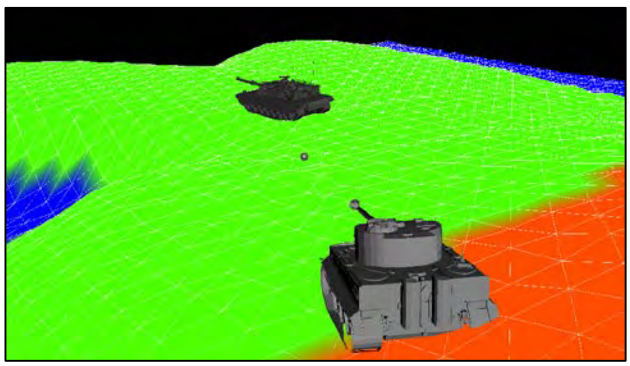

Fig. 6 Tank combat game application

- **ARES Scalability**
  Based on user requirements, a squad-sized version of ARES (7 × 4 ft) is under construction, and future scalability needs are being evaluated.

- **After-Action Review Tools**
  Develop and evaluate tools to support after-action reviews of simulations or live training events.

9. Desired Future Research Questions and Capabilities Development

The following list consists of capabilities we aim to develop and various research questions:

- **Dynamic Projection Mapping**
  Support for complex surfaces so projected images do not look "warped" on sand topology.

- **Connection to Geographic Databases**
  Research is needed to determine the best method of providing cues to the user that would prompt them to shape the sand to correlate to a geographically specific area of operation.

- **Hand/Finger Tracking for Unit Placement and Command**
  Incorporating tracking capabilities that will provide users the ability to select and move objects by pointing at locations on the sand. Refinement of hand tracking sensitivity is needed to support the development of a gesture set that can be used to intuitively command and control units.

- **Military Map Features**
  Inclusion of military overlay data, such as grid lines, military grid reference system coordinates, tactical landmarks, and elevation notation.

- **Augmented Reality to Improve Data Visualization and Decrease Cognitive Load**
  Technology that will allow certain information to "pop" up off the sand when viewed through a mobile device or AR goggles. For example, users can see communications networks or tall structures that may impede air support above the topography.

- **Affective Benefits of ARES as a TUI in a Military Context**
  Research study to determine if ARES users see an increase in engagement, collaboration, and interactions and what effect that has on learning and performance outcomes.

- **Incorporation into Live Events**
  Integrated with Force XXI Battle Command Brigade and Below (Army) / Instrumented-Tactical Engagement Simulation System (Marines) technology to import and display unit locations and states in real time on ARES for improved understanding of the operational picture.

- **Man-Portable Form Factor**
  Leverage COTS mobile device sensors and mini-projection technologies to provide a reduced-scale version that can be carried by a user and projected onto any surface (Fig. 7).

Fig. 7 Concept of mobile version of ARES

- **Can ARES be used for more efficient terrain and scenario generation?**
  The capability to author and export 3-D terrains and scenario settings in standardized formats will be developed and tested. This will allow subject matter experts (SMEs) and instructors to create content on ARES and export the content to other simulation and game applications (OneSAF, VBS3, etc.) more efficiently than via traditional methods and without requiring the highly specialized skills of platform-specific scenario authors and 3-D artists.

- **Can distributed users collaborate more effectively?**
  The distributed, accurate common operational picture on ARES will be used as a testbed to determine if joint and coalition partners can collaborate on tasks, such as exercise planning and tactical war-gaming in a more intuitive and cost-effective manner.

10. ARES Research Methodology

ARES research began with a literature review of current sand table use, specifically STEX (i.e., how they have been used historically and best practices for their use); studies on related topics, such as the benefits of tangible user interfaces; and the effectiveness of virtual sand tables and similar systems. A market survey was also done to discover the state of the art in related technologies.

Next, an analysis was conducted to identify potential use cases, military end users and stakeholders, and core functionalities and features that users would require of ARES. This analysis included trips to the 199th Infantry Brigade at Ft. Benning and to The Basic School at Quantico Marine Corps Base to speak with and observe SMEs. SMEs from both services were enthusiastic about ARES and provided use cases where ARES is capable of enhancing training throughout their leadership courses. The findings of this analysis were used to define the initial capabilities and scope of the ARES proof-of-concept table along with identifying the required research.

Using only mission funding internal to STTC, we constructed an ARES proof-of-concept table to determine feasibility to support research studies and to demonstrate the concept to potential stakeholders, collaborators, and users for requirements definition.

11. ARES Research Experiments

Several studies using ARES are being conducted to define the benefits of sand table interactions:

- Charles Amburn, principal investigator for the ARES project, is conducting a study with 2 main objectives: 1) to determine the extent to which ARES is capable of significantly improving spatial knowledge acquisition above and beyond existent training mediums (paper map and 2-D display of 3-D rendered objects) and 2) to provide a foundation for establishment of a learner-centric environment using novel technology. Essentially, the hypothesis is that users viewing maps on the sand are more effective and efficient than those using 2-D printed maps or even 3-D digital representations presented on a 2-D plane (e.g., an LCD monitor or tablet).
- Michael Boyce is currently conducting a study, "The Effect of Topography on Learning Tactical Maneuvers", wherein he is assessing the effects of ARES' 3-D surface on learning tactical military knowledge. The Department of Military Instruction at the United States Military Academy (USMA) is assisting with the pilot study, which is planned to become a full study to be conducted at USMA in FY16.

12. ARES as a Service

ARES is built on a service-oriented architecture that is modular and extensible, allowing for customization to meet individual user needs. Now that the ARES software and interface protocols are published, other users (e.g., Army, Department of Defense [DOD], and other government agencies) can leverage the technology in new ways. This flexible approach and open interface allows for 2 primary benefits:

- ARES can be updated easily and cost effectively, taking advantage of the latest advances in sensor, projector, and augmented reality technologies.

- ARES becomes a platform, similar to iOS or Android, where users will create their own apps to support their individual needs.

Figure 8 illustrates the goal of extending core capabilities with applications and services to support a myriad of training and operational tasks.

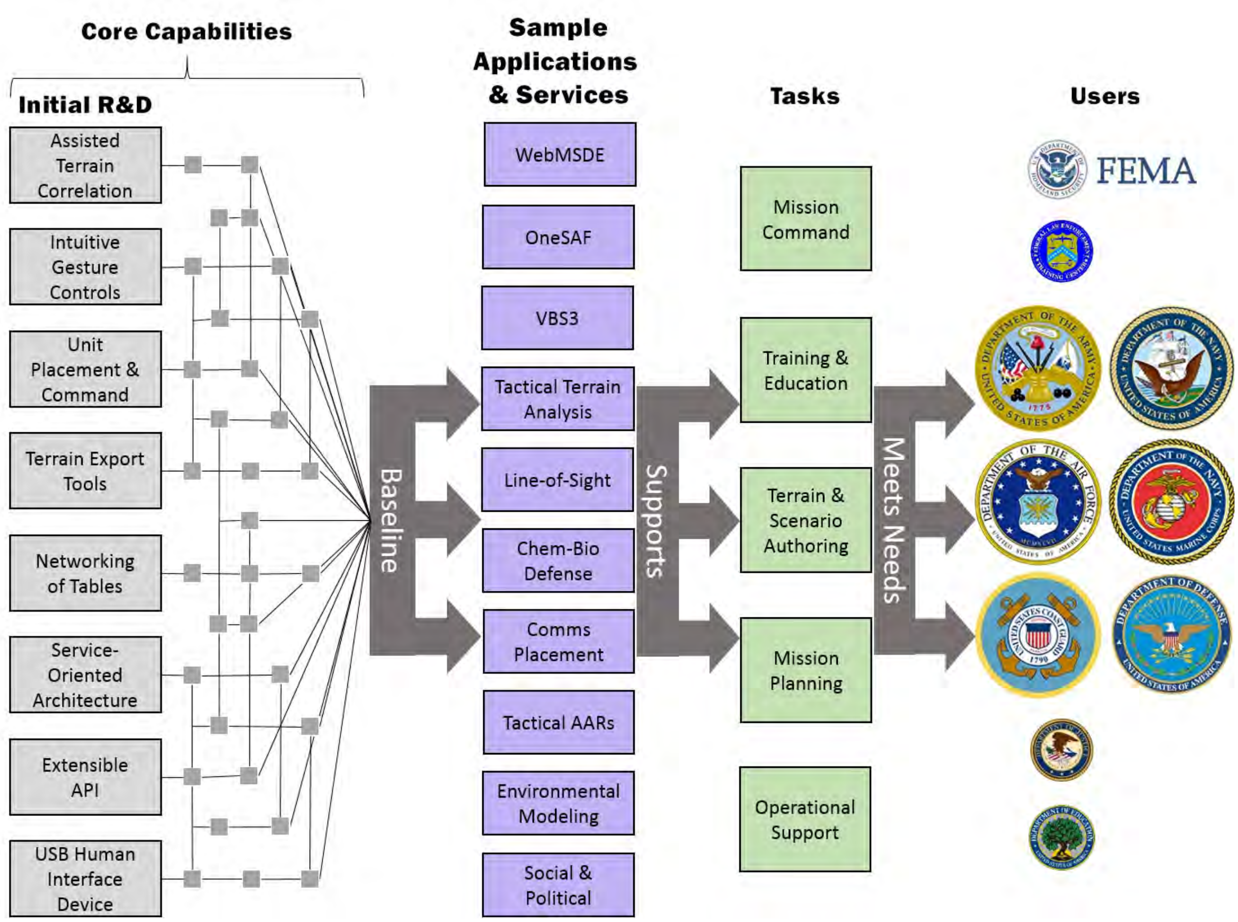

Fig. 8 An open ecosystem of cooperating services and capabilities that can be combined to meet end-user needs

13. ARES Reuse of Existing Technologies

ARES uses an open systems architecture that is modular and extensible. It already successfully leverages several existing technologies developed by ARL. Table 2 outlines reused technologies.

Table 2 ARES reuse of existing technologies

Integrated technology	Technology description	Specific integration with ARES
Rapid Unified Generation of Urban Databases (RUGUD) http://www.rapidterrain.com	RUGUD is a government off-the-shelf data processing framework that can assist in the conversion of terrain data into alternate formats to be used by other applications.	RUGUD is used with ARES as a mechanism to translate other terrain formats into formats that ARES can understand.
Layered Terrain Format (LTF) (Peele et al. 2011)	LTF is a high-resolution 3-D terrain representation format that can be rendered on hardware and software constraint devices, such as a hand-held.	LTF is used with ARES as a part of its tablet-based interaction platform facilitating mission planning and LOS.
Tactical Terrain Analysis (TTA) App (Borkman et al. 2010)	The TTA app provides a line of sight (LOS) service that can provide a fan representing the field of view at a given location, incorporating occlusion for areas that are blocked because of obstructions.	ARES uses the TTA app functionality to determine LOS given a particular terrain topology, such that it changes dynamically as the sand is manipulated.
Soldier Training Enhancement Package (STEP) 3D App (Roberts and Chen 2009)	The STEP 3-D App is an augmented reality tool that allows for buildings to appear in 3-D when viewed through a tablet.	STEP 3-D is used on ARES in conjunction with recognition markers to cause buildings to show 3-D height on the sand.
Upcoming integrations	**Technology description**	**Specific integration with ARES**
Generalized Intelligent Framework for Tutoring (GIFT) (Sottilare et al. 2012)	GIFT is a modular, service-oriented architecture developed to assist in the authoring and development of Intelligent Tutoring Systems.	GIFT will provide ARES with the capability to author adaptive training experiences that can adjust to the needs of an individual learner.
Web-Based Military Scenario Development Environment (WebMSDE) (Marshall et al. 2013)	WebMSDE is a scenario generation tool that can be executed within a browser. It has a robust user interface and can efficiently generate scenarios in a wide variety of formats.	WebMSDE may provide ARES with distributed OneSAF scenario generation capability as well as access to its existing scenario libraries.

14. Evaluations

Several instances of the ARES proof of concept have been strategically coordinated with stakeholders for continued evaluation of current capabilities and the development of future research requirements. For example, the Office of Naval Research (ONR) has provided funding for ARES to be evaluated in Quantico by the Marine Corps' The Basic School. Feedback has been positive, and they expressed eagerness to run force-on-force training with networked ARES tables. Additional desired capabilities have been submitted through ONR, including the intent for ARES to scale up to cover the large 16-ft battalion-sized sand tables they use.

Per a March 2014 Memorandum of Understanding (MOU) with USMA at West Point, STTC provided an ARES prototype to the Engineering Psychology Program of the Department of Behavioral Sciences and Leadership at USMA where first class cadets (seniors) in the Engineering Psychology program have conducted initial usability, workspace, and workload assessments as part of their final human factors design course. ARES is also being used by cadets learning to conduct Operational Order (OPORD) briefs as a part of their military instruction curriculum (Fig. 9).

Fig. 9 Cadet at West Point performing OPORD briefing on ARES (image courtesy of the Engineering Psychology Program, Department of Behavioral Science and Leadership, United States Military Academy, West Point)

Under a different collaboration between ARL and the 211th Regional Training Institute, the Florida National Guard has provided funding for an ARES prototype to be delivered to Camp Blanding for evaluation and research collaboration by first-quarter 2016.

STTC is currently working with the Rapid Equipping Force to place one or more ARES prototypes within operational units to conduct evaluations and experiments related to effectiveness and efficiency. The initial insertion is being coordinated with the 3rd Infantry Division at Ft. Benning.

Work is also being done under the scope of joint/coalition training research at STTC to integrate a distributed scenario authoring tool (WebMSDE) and to improve the distributed collaboration capabilities in order to be evaluated ARES with joint/ coalition partners.

15. Demonstrations and Key Leader Engagements

In seeking additional stakeholders and collaborators, the ARES project has been a part of several hundred demonstrations and discussions with DOD senior leadership, members of Congress, representatives from other interested agencies, and foreign militaries.

ARES has been briefed and discussed at the following locations:

- Simulation and Training Technology Center
- Program Executive Office for Simulation, Training, and Instrumentation (PEO STRI)
- 143rd Expeditionary Sustainment Command
- 2014 Interservice/Industry Training, Simulation, and Education Conference
- Modern Day Marine 2014
- Navy Future Forces 2015
- Human Factors Engineering Technical Advisory Group in May 2015
- 2015 Association of the United States Army Global Force Symposium and Exposition (Fig. 10)

Army leaders who have recently provided extremely positive feedback and guidance include Major General Wharton (Commanding General, US Army Research, Development, and Engineering Command), Major General Maddux (PEO STRI), General Perkins (Commanding General, US Army Training and Doctrine Command), General Via (US Army Materiel Command Commanding General) and General Odierno (Chief of Staff of the Army).

Fig. 10 ARES being briefed to General Via at AUSA 2015

16. The Way Forward

The Science and Technology activity at ARL HRED STTC will use mission funds to cover some of the initial research required, and STTC will make some form of it available to selected units to conduct evaluations and/or experiments. To fully evaluate its potential, ARL HRED STTC needs support in defining a US Army Training and Doctrine Command (TRADOC) requirement and a transition path. Although some of the basic initial research is currently underway, funds must be injected from sources outside of STTC to further the research and enable ARES to reach Warfighter needs. Once a requirement and funding are in place, an acquisition strategy will be set forth to transition the technology to a program of record for fielding and sustainment.

ARES is a rare project that sparks the imagination in almost everyone who interacts with it. There is something intangible about the tactile medium that draws them in, makes them comfortable, and makes them want to explore and create. With modern, low-cost technologies, the nature and benefits of these interactions can be studied and leveraged in ARES and other Army projects. What if all training made you feel engrossed and energized? What if all mission planning tools encouraged creative thinking? And what if all modeling and simulation systems felt intuitive, logical, and natural?

Given the practical limitation on how much information a Warfighter can effectively handle, further research in the realm of presenting Warfighters with tangible, intuitive interfaces that allow for them to reveal layers of data based on specific mission requirements is an imperative. The principles that we learn from ARES can be applied to create new forms of data visualization and computer interaction. Continued ARES research will enable a set of standards for ambient computing—where the room around you is the display (not just your flat computer monitor) and the tools around you (your hands, the pencil, and coffee mug on your desk) will be used to explore the data you need to fully understand the mission and share that understanding effectively.

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List of Symbols, Abbreviations, and Acronyms

3-D	3-dimensional
AR	augmented reality
ARES	Augmented REality Sandtable
ARL	US Army Research Laboratory
COTS	commercial off-the-shelf
DOD	Department of Defense
GIFT	Generalized Intelligent Framework for Tutoring
HMD	Head-Mounted Display
HRED	Human Research and Engineering Directorate
LOS	line of sight
LTF	Layered Terrain Format
MOU	Memorandum of Understanding
OneSAF	One Semi-Automated Forces
ONR	Office of Naval Research
OPORD	Operational Order
PDA	Personal Digital Assistant
PEO STRI	Program Executive Office for Simulation, Training, and Instrumentation
RUGUD	Rapid Unified Generation of Urban Databases
SME	subject matter expert
STEP	Soldier Training Enhancement Package
STEX	sand table exercises
STTC	Simulation and Training Technology Center
TRADOC	US Army Training and Doctrine Command
TTA	Tactical Terrain Analysis
TUI	tangible user interface
USMA	United States Military Academy

VBS3	Virtual Battlespace 3
VR	virtual reality
WebMSDE	Web-Based Military Scenario Development Environment

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