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DETERMINING THE UTILITY OF ADVANCED DISTRIBUTED SIMULATION TO TEST AND EVALUATION

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ABSTRACT

This paper summarizes efforts taken to date by the Joint Advanced Distributed Simulation (JADS) Joint Feasibility Study (JFS) team in determining the utility of Advanced Distributed Simulation (ADS) to test and evaluation (T&E). The top-rated of the many T&E requirements that may be satisfied by ADS are reviewed, as well as eight applications of ADS identified by the team. The study team has concluded that ADS is a viable tool, but knows that the T&E community needs quantitative data on ADS performance. Thus, specific tests are planned by the team, two of which are discussed here. The Systems Integration Test involves linking traditional hardware-in-the-loop simulation with live open-air aircraft. The End-to-End Test replicates a thread of the battlefield process, from target detection to target destruction, using a combination of actual hardware, simulations and models. Finally, some of the proposed JADS joint test and evaluation (JT&E) legacy products are discussed, in light of their importance to members of the T&E community accepting ADS as a creditable tool.

1 INTRODUCTION

In this paper, I discuss some of the efforts that the JADS JFS team has taken to date. JADS JFS is a year-long technical study chartered by OSD's Director of Test and Evaluation. The team's charter was to assess whether it is necessary and feasible to conduct a joint test to determine the utility of ADS to support T&E. Actual quantitative data on the performance of ADS as a methodology, or test tool, would need to come from test performance. The study team, therefore, is also responsible for preparing initial plans for a JT&E that would measure ADS performance in several areas of T&E activities.

As used by the study team, the term ADS refers to the technologies of distributed interactive simulation (DIS), but not limited to the DIS architecture and protocol standards established by the University of Central Florida (UCF). Advanced refers to means or concepts not done previously, encompassing both existing and emerging capabilities. Thus, existing models, simulations, laboratories, test range facilities, hardware, etc. as well as emerging capabilities are included in the term ADS.

The proposed joint test of ADS is a timely analysis of a new test tool that can potentially enhance the T&E process. Senior Defense leaders have long called for a streamlining of the acquisition process in light of austere budgets and perceived inefficiencies. Likewise, conventional methods of T&E have come under scrutiny. New weapons systems can no longer be satisfactorily tested using conventional means, while tight budgets and limited resources challenge members of the T&E community to come up with innovative ways to test realistically and thoroughly. Many see ADS as the answer, but little quantitative data on the performance of this potential methodology exists. Members of the T&E community, as well as acquisition program offices, are not likely to invest their time, effort and resources on an unknown quantity. The utility of ADS as a T&E methodology must be proved -- where it works well, and where it doesn't. The JADS JFS team has determined that such a test of ADS is needed and, in most cases, technically feasible.

This paper is organized as follows. First, the top-ranked T&E requirements that may be satisfied through the use of ADS are reviewed. Next, eight applications of ADS methodology identified by the team are summarized. A brief description of two of the team's proposed ADS test plans follows. Finally, recognizing the difficulties involved in convincing a community to embrace a new concept, legacy products designed to ease the paradigm shift are discussed.

2 TEST AND EVALUATION REQUIREMENTS

The first step in determining ADS' utility to support T&E was to look where the need for improvements to T&E methodologies had been documented. To do this, an assessment of limitations, or shortfalls, to past and planned testing was made. If there were no desired improvements documented which ADS might resolve, then adding ADS as a T&E methodology would be a costly and unneeded duplication of capabilities.

The sources of the identified shortfalls, or limitations, were Test and Evaluation Master Plans, test plans, test reports, interviews and lessons learned documents. Some 361 separate shortfalls were identified, then rank ordered by members of the three Services' operational and developmental test (OT and DT) communities. These shortfalls in turn became requirements for the investigation of ADS in the hopes that ADS could overcome some portion of these historic limitations. The top-ranked OT and DT limitations or shortfalls are summarized in Table 1.

Table 1: Top-Ranked OT and DT Test Limitations

TOP OT LIMITATIONS
Inadequate Quantity and Types of Targets
Inadequate Quantity and Types of Threat Systems
Inadequate Quantity and Types of Friendly Systems
Electronic Combat Testing Not Allowed, is Limited or Restricted
Non-Representative Force Levels
Human Interaction Not Represented
Insufficient Test Articles
Unrealistic Test Scenarios
Insufficient Number of Test Events
TOP DT LIMITATIONS
Inability to Integrate Avionics Testing
Limitations to Testing Special Access programs
Incompatibility of Collected Data
Human Interaction Not Represented
Non-Representative Force Levels
Inadequate Quantity and Types of Threat Systems
Electronic Combat Testing Not Allowed, is Limited or Restricted
Lack of Systems for Compatibility Testing
Real-Time Modeling/Simulation Not Available

In addition to studying where ADS might overcome historical T&E shortfalls and limitations, the team identified innovative uses of ADS, to allow results not previously attainable. These innovative uses are described below.

Electronically integrate threats and Time-Space-Position-Indication (TSPI). When testing a weapon system, enemy threats must be simulated in most cases either in type, numbers, or both. Threat simulators are located throughout the country, and ADS may provide a means of linking these simulators to provide an integrated threat environment which can then be linked to the test system for a more realistic battlespace.

Flexible Command, Control, Communications, Computers, Intelligence (C4I) testing. ADS may provide a means of adding friendly forces in the battlespace such as robust and flexible C4I networks, and high-value assets in limited supply. Portions of a C4I network can be represented by ADS to provide more robust C4I either to augment a system in test or as a support.

Linking of range capabilities. ADS may be used to increase the number of supporting test assets by linking several ranges together. This could provide a more robust operational environment for electronic combat testing, or allow the use of limited range assets at another location without the expense of doing the testing at multiple locations.

Interoperability. Single Service tests of systems that play in a joint battlespace arena routinely have the problem of testing interoperability with other Service assets, particularly high-value assets in limited supply. ADS may provide a means of testing interoperability with a much larger population of other Service systems through the use of distributed simulations.

Test concept validation. ADS technology may have applications as a better, more cost efficient method of structuring a test when used for advanced planning and test planning. Testers may be able to use it for sensitivity and parametric analyses, determining data requirements and test concept validation long before any major portions of the systems are built.

Real time casualty assessment/removal. ADS technology shows promise for allowing real time, human interactive casualty assessment. The problems of casualty assessment and kill removal have always been a problem in live tests because a live system may not know that it has been killed and will continue to fight for some period of time, impacting the actions of other systems.

Flexible test environment with innovation. ADS may provide a way of using virtual prototypes, with open architecture software, to permit quicker component capability changes in order to obtain the final system design or configuration during developmental testing. ADS may also provide a means of changing test environments to operational environments not readily available using existing test facilities.

Test rehearsal. This application of ADS is related to the use of ADS for test planning. It may provide a more efficient method of maximizing live test time by wringing out the system prior to actual live testing, and by focusing the live test time on specific problem areas.

Live/virtual mix. This is the basic application where ADS appears to have large benefits in thickening the battlespace for the few live players in a test. It also may provide an opportunity for evaluating human factor and live response/reactions in those situations where safety or environmental restrictions limit testing.

3 ADS T&E METHODOLOGIES

By using both these historical T&E shortfalls and innovative uses as requirements, ADS technology could now be examined to determine how these requirements might be satisfied. The study team identified eight applications, or methodologies of ADS that might satisfy many of these requirements. These eight methodologies are described below:

3.1 Add Assets

ADS may be used to increase the number of test assets, increase the number of supporting assets, and add assets (e.g. targets, threats, integrated air defense systems [IADS], communication networks, etc.) that are not available. Major subcategories include:

3.1.1 ADS Representation of Foe Targets, Threats and IADS

When testing weapon systems, foe forces and systems must be simulated in most cases either in type, numbers or both. ADS may provide a technology to simulate the necessary capabilities and characteristics and link that presentation with the system under test. The simulations may be a mix of live, virtual and/or constructive and include human interaction where necessary. This application is an alternative to using friendly systems to represent foe systems. It also includes connecting systems from separate ranges together to get more types and numbers. For example, it may now be possible to internet several electronic combat (EC) test ranges to get a more representative mix of threat systems.

3.1.2 ADS Representation of Friends, Systems and C4I

ADS may provide a means of adding additional friendly forces in a battlespace, including robust communications networks and high value/limited supply friendly systems. It appears possible to link production articles with simulators of the system to provide a more representative fighting unit to test. Portions of a C4I network can be represented by ADS to provide more realistic, more interactive, and more robust C4I either to augment a system in test or as a support system. In EC testing, safety and environmental/security considerations often restrict the testing of radiating systems, both for the system under test and for supporting systems. ADS may provide a means of linking live systems and open air ranges with threat simulations and EC hardware in anechoic chambers to evaluate system capabilities and characteristics including real-time operator responses. In weapons testing, ADS may provide a means of using interactive simulations with hardware-in-the-loop to test features that are difficult to operate live due to restrictions, such as firing lasers, launching multiple missiles, and expending countermeasures. ADS may also have the capability to link multiple Service simulations and systems to provide assets for interoperability testing.

3.2 Increase Test Length, Events and Repetitions

With ADS it may be possible to perform more test events, do multiple repetitions of particular events, or decrease the length of a test. In this application it usually will be necessary to replicate the actual test event, or events that one wishes to study further. It also will be necessary to either connect the test system to an ADS network, or in some cases to simulate the item under test when additional tests are performed. For example, a tester may shoot a small number of live missiles and then simulate the shooting of many more missiles using a validated simulation. This simulation may consist of actual hardware in the loop with only simulated firings, or it may be a computer simulation of the missile itself, depending on the measures being evaluated.

3.3 Real-Time Endgame Analysis/Damage Assessment

As mentioned before, ADS shows promise for allowing real-time, human interactive endgame analysis. It also helps solve some of the problems of damage assessment usually found in live testing scenarios. Currently in live testing, results of combat interactions between fighting entities prove to be either inconclusive or misleading. For example, in a mock battle between live tanks, the only result known is that a tank received a simulated hit. Data is not available instantaneously to

determine where it was hit, whether it was a total kill, or whether damage allows it to continue moving but not firing (or to continue firing but not moving). ADS may provide a method of determining what part of he vehicle was hit and what class of damage occurred.

3.4 Human Factors/Live Response

It is sometimes difficult to provide and test human responses and reactions because of safety or environmental restrictions. ADS may provide a test capability to safely inject a human in the loop to add more realism and determine responses and reactions that otherwise could not be tested. For example, reactions and responses when flying at very low altitude, when under combat fire, or in nuclear, biological or chemical (NBC) environments could be tested in an interactive scenario tied to other systems and live players connected through ADS. This application considers human responses and reactions associated with the test article, human responses and reactions from other systems to the test article, or a combination of both.

3.5 Test Planning

ADS may provide a better, more cost efficient test of a system if it can be used to improve advanced planning, test planning and test rehearsal. This applies both for DT and OT. It may aid sensitivity and parametric analyses, test design, data requirements determination, and problem identification through test rehearsal. In the past, constructive simulations have been used both in support of DT and OT. The advantage gained by using ADS is that the artificial decision tables inherent in most constructive simulations are replaced by decisions made by the human participants.

3.6 System Development

There are several possible uses of ADS technology in the system development process all the way from early requirements development through evaluation of possible future product improvements. The major subcategories include:

3.6.1 Use of ADS in Requirements Development

By using a virtual prototype or constructive simulation of a proposed system interacting with a network in realistic battle scenarios in real time, users and developers may be able to derive better operational requirements that produce the desired battlefield effectiveness. This would also aid in identifying and establishing the minimum acceptable requirements and key system parameters, and may at the same time identify interoperability issues with other systems.

3.6.2 Use of ADS in Performing Cost and Operational Effectiveness Analyses (COEAs)

By using ADS, users and developers may be able to evaluate operational effectiveness of proposed alternatives and design approaches against parameters using a network that includes most likely scenarios, friendly systems, validated threats, environmental factors, and other constraints or assumptions. With ADS, it may be possible to quantify the operational impact of employing each alternative under consideration.

3.6.3 Use of ADS in Trade Study Support

ADS may provide a way of using virtual prototypes, with open architecture software, to perform studies trading system performance parameter values in realistic battle scenarios, and also permit quicker component capability changes in order to obtain the final system design or configuration. This could lead to a reduction in number and time span of design-test-fix cycles. These virtual prototypes could also be used for operational evaluation of the system prior to source selection.

3.6.4 Use of ADS in System Specification Validation

By using hardware-in-the-loop simulations tied to realistic synthetic battlespaces, it may be possible to validate specification compliance while demonstrating operational capability or even exploring expansion of the system's performance envelope prior to moving the system into operational testing.

3.6.5 Use of ADS to Evaluate Product Improvements

Following live testing of a system, the virtual model of the system could be validated using real performance data, and then used in an ADS environment to quantify the value of future planned product improvements.

3.7 Environmental Robustness

ADS may provide the means to test a system in operational environments that are not readily available using existing test ranges. This application includes the broad range of environments of atmospheric (both air and space), sea and land across the varying climatic zones. Robust environments also include situations

such as NBC, which are never available for testers. This is the one area of ADS applications that the study team feels is not sufficiently mature to examine during the life span of the proposed JT&E.

3.8 End-To-End Testing and/or Post-Test Evaluation

During test execution, with ADS it appears feasible to connect a system with a representative suite of friendly assets in an end-to-end test for evaluation of the contribution of a system to the battlespace destruction of a target. In addition, ADS may provide an analysis tool, once live testing is complete, to evaluate the system by taking the live data and using it in a distributed simulation to generalize the results and determine the operational effectiveness of the system. This would be a case of the model-test-model methodology. If the thickening of the battlespace and interoperability between systems is sufficiently representative of a theater conflict, ADS may also help support an evaluation of a system at a battle outcome level. This application primarily deals with the possibility of using ADS as an evaluation tool once the live test data has been collected.

4 ADS TESTS

The preceding ideas on T&E requirements and ADS applications are just that -- good ideas. However, they will do little to enhance the effectiveness of T&E activities unless ADS is used, effectively, as a T&E tool. Before the T&E community is going to embrace ADS, however, they need hard data about the technology -- where it works well, where it doesn't, and how best to use it when appropriate.

The proposed JADS JT&E is designed to provide both the analytical data on ADS performance, as well as a cookbook on how to use ADS tools. Recognizing the enormity off the spectrum of T&E activities, and the limitations of performing a three or four year joint test, specific areas were chosen for examination. These areas represent significant portions of T&E activities. Additionally, broader examination and conclusions will be drawn, when possible, on areas of T&E activity not specifically tested by the JADS JT&E.

There are currently three tests proposed by the JADS team for use in determining the utility of ADS as a T&E methodology -- the System Integration Test, the Electronic Combat Test, and the End-To-End Test. The End-To-End Test also has a large excursion examining the utility of ADS in supporting EC testing of a communications link. Due to space, the Electronic Combat Test and EC excursion of the End-To-End Test will not be covered here.

4.1 System Integration Test

This is a two-phased test involving the application of six of the eight T&E methodologies to the T&E of a precision guided weapon. The Advanced Medium Range Air-to-Air Missile (AMRAAM) was chosen as the system under test by which to evaluate ADS utility, due to the wealth of baseline T&E data from conventional testing. The goal is to replicate AMRAAM fight tests using ADS with a combination of actual hardware, hardware-in-the-loop (HWIL), digital simulations, and an open air range with live aircraft. A summary of ADS methodologies examined by phase is in Table 2.

Table 2: System Integration Test Summary

Test Phase	Resource	ADS Methodology
1	- Live Aircraft - HWIL Simulation	Test Planning
1	- Live Aircraft	- Add Assets - Increase Test Repetitions - Real-Time End-Game Analysis - Human Factors - System Development
2	- Live Aircraft - HWIL Simulation - Aircraft Simulator	- Add Assets - Increase Test Repetitions - Real-Time End-Game Analysis - Human Factors - System Development

In Phase 1 of this test scenario, a launch aircraft with an AMRAAM Captive Equipment (ACE) pod flies against a live maneuvering target aircraft. Spatial position data from both the launch and target aircraft and telemetry data between the launch aircraft and the ACE pod are downlinked to the range Central Control Facility (CCF). When the launch aircraft reaches firing parameters, rather than fire a live AMRAAM at a drone resulting in the expenditure of both, the fire signal and subsequent midcourse guidance update signals are downlinked to the CCF and passed to an anechoic chamber, where an AMRAAM missile is

installed in a HWIL simulator. The missile performs a flyout toward the target using actual midcourse guidance updates and completes its intercept using a background target scene simulation driven by the position updates of the actual maneuvering target aircraft.

Phase 2 of the test will incorporate the same elements, except the live flying will be relocated cross-country from the HWIL simulator and CCF. Additionally, a manned aircraft simulator at a third location will also be used, providing an additional target and examining a mix of live and virtual entities. Both locations and the associated data streams will be networked cross-country.

The potential benefits include cost savings of missiles and drones, being able to simulate multiple targets including electronic countermeasures, multiple launches per sortie vice a single live shot, operationally realistic target aircraft and maneuvering, the ability to utilize geographically separated test facilities, test rehearsal and problem identification prior to shots, and integrated avionics system testing. A graphic of Phase 2 of the System Integration Test is in Figure 1.

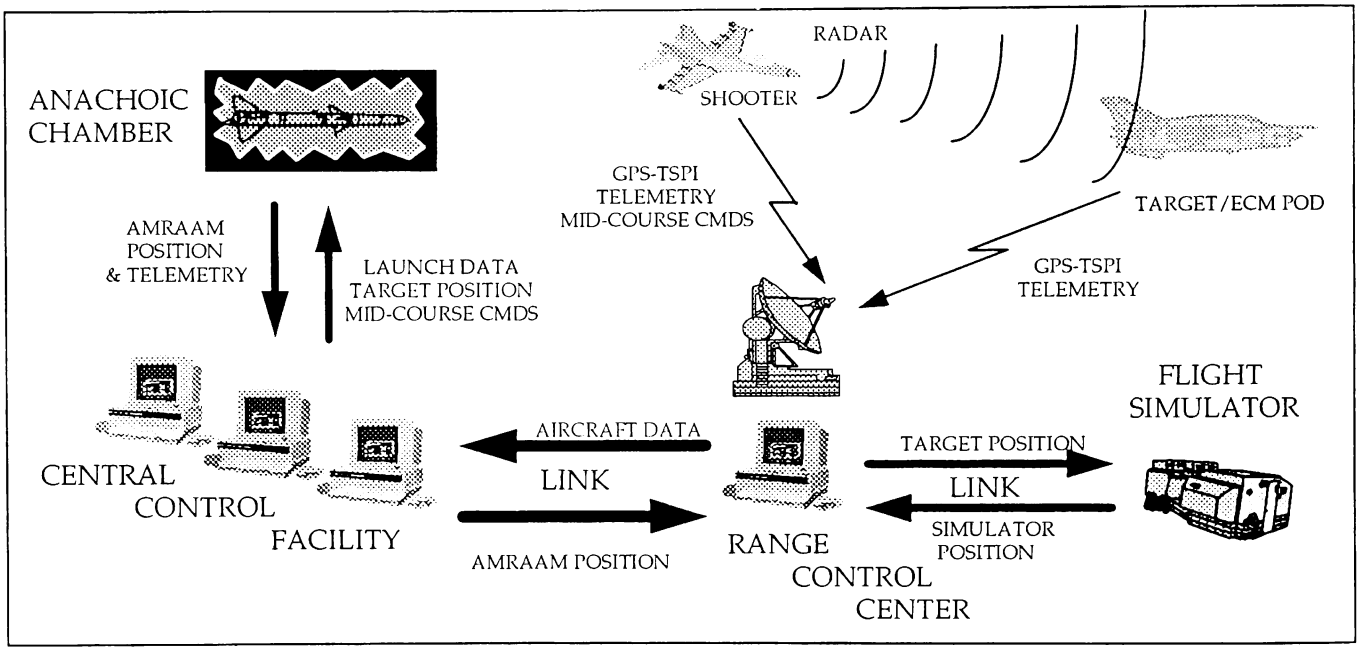

Figure 1: Phase 2 of the System Integration Test

4.2 End-To-End Test

This is a four-phased test to evaluate the utility of ADS T&E methodologies to support end-to-end analysis in a theater-level test scenario. The scenario will use a combination of actual weapon systems linked to HWIL and man-in-the-loop simulators and constructive digital simulations. The primary systems of interest are the Joint Surveillance Target Attack Radar System (Joint STARS) E-8C aircraft and Ground Station Module (GSM). Supporting systems include a model of the Army Tactical Missile System (ATACMS), Unmanned Aerial Vehicle (UAV) model, HWIL C4I nodes such as Fire Detection Center (FDC), Fire Coordination Element (FCE), All-Source Analysis System (ASAS), tactical fire (TACFIRE) message traffic via Single Channel Ground and Airborne Radio System (SINCGARS), etc. These systems were chosen as representative examples of C4I and weapons systems for all four Services. The test examines five of the ADS methodologies, as shown in Table 3.

The overall scenario, which will be constructed and tested in phases using ADS T&E methodologies, will link an E-8C and a UAV to the GSM to provide surveillance targets data which will be passed through appropriate decision-making nodes and then to ATACMS for missile launch and target destruction.

This will provide a representative thread from target detection to target destruction for an end-to-end evaluation. Traditional test data and Operation DESERT STORM data on the Joint STARS E-8 and GSM will be used for baseline comparison to determine ADS' utility.

Table 3: End-To-End Test Summary

Test Phase	Resource	ADS Methodology
1	- E-8C Replicator - Constructive Model - GSM Replicator	Add Assets
2	- E-8C Replicator - Constructive Model - GSM Replicator - DIS Network - C4I & Weapons Nodes	- Add Assets - Endgame Analysis - Human Factors, Live Response - Test Planning - End-To-End Test
3	- E-8C Aircraft - Constructive Model - GSM - DIS Network - C4I & Weapons Nodes	- Add Assets - Test Planning
4	- E-8C Aircraft - Constructive Model - GSM - DIS Network - C4I & Weapons Nodes - Ground Exercise	- Add Assets - Endgame Analysis - Human Factors, Live Response - End-To-End Test

Potential ADS benefits include the ability to add operational realism through theater-representative quantities of interacting ground targets for the E-8C and GSM, human interaction in both systems including representative C4I threads, test rehearsal identification of potential problems, cost savings from using virtual simulations of UAV and ATACMS systems as well as bolstering the limited number of live ground forces using constructive entities, and the capability for an end-to-end evaluation from target identification through destruction. A graphic of Phase 4 of the End-To-End Test is in Figure 2.

5 LEGACY PRODUCTS

What the T&E community does not need is another test report collecting dust in someone's library. If ADS methodologies are going to be incorporated into T&E effectively, then there must be a wide selection of legacy products available to encourage the process. The JADS team recognizes this, and has made legacy products a major objective of the proposed JT&E. A partial list follows:

ADS test tools, actual pieces of hardware developed for the JT&E, will be available to the T&E community for use in other programs. Examples include new PDUs, instrumentation, interface units, enhanced models and simulations, and upgraded E-8C and GSM replicators.

A roadmap will be provided by JADS to the ADS/DIS communities, providing guidance in shaping further technological development and allowing the needs of the T&E community to be better met.

During the JT&E, JADS will use the most effective of DOD and Service direction on Verification and Validation (V&V). A recommendation will be made based on JADS' experience in this area on the most effective V&V procedures.

Additionally, two libraries will be left as legacy products of the JT&E. One is the reference library, containing all ADS-related material collected during the JFS and JT&E. The other will be the data library, containing all data collected during the JT&E. Whichever organization or organizations take responsibility for the institutionalization of ADS would be the recipients of these libraries.

Information briefings will be provided throughout the lifecycle of the JT&E, both face-to-face and via video. The importance of educating the T&E community cannot be underestimated, and must not wait until the end of the JT&E. Frequent and widespread briefings will inform the T&E community where the technology has shown cost benefit or value added. Periodic newsletters, TECHNET bulletin boards and articles will also help spread the word.

Anticipating the wide availability of CD-ROM in three to four years, an interactive training module will be distributed throughout the T&E community. It will serve as an excellent cookbook by which potential ADS users can educate themselves, learn what ADS applications are germane to their program, determine what components they should incorporate into their program, and find the right experts to contact for detailed assistance. A resource list of simulations and facilities available with their usefulness to T&E, strengths and weaknesses, cost, etc., is essential to the project. Network architecture design examples could provide ease in developing a test concept for using ADS methodologies.

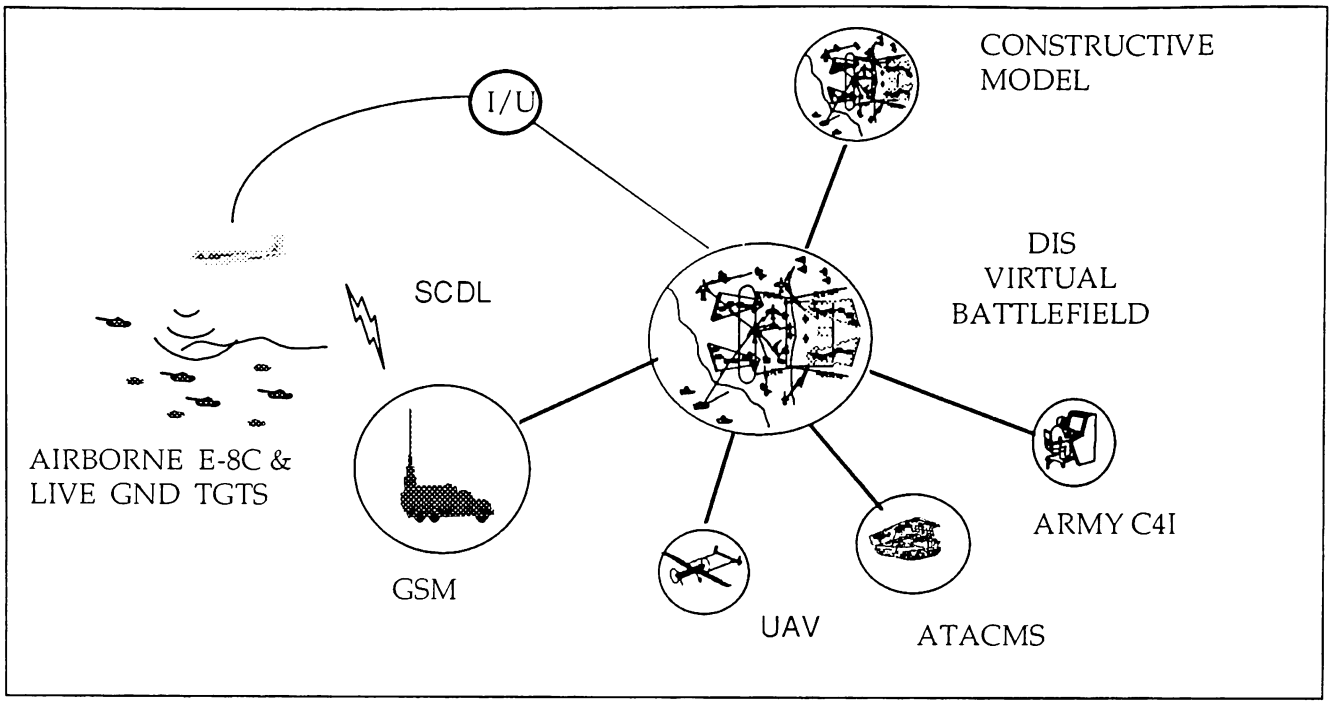

Figure 2: Phase 4 of the End-To-End Test

6. CONCLUSIONS/RECOMMENDATIONS

The JADS team has quantified the necessity and feasibility of performing a JT&E of ADS in order to determine its utility as a T&E methodology. Many historical shortfalls could perhaps be rectified through ADS, and innovative uses of ADS may provide T&E results not previously attainable.

ADS holds great promise, but factual data must be obtained on ADS performance in T&E applications to clearly determine where ADS can provide value added. Therefore, the JADS JT&E should be conducted at the earliest opportunity in order to start stripping away the mystique and providing testers and evaluators with new, yet solid, tools of the trade.

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