

UCAV Distributed Mission Training Testbed: Lessons Learned and Future Challenges

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Abstract

The UCAV DMT Testbed research will focus on technologies for: defining effective training strategies for UAV/UCAV operators; assessing the delta in training required for multiple vehicles; advanced displays driven from human factors design; integration of Geneva Aerospace's Variable Autonomy Control System; and integrating several UAV and UCAV Flight Model into the Testbed. Potential applications include direct linkage of UCAV Testbeds as Participants in DMT. This paper chronicles the development of the UCAV DMT Testbed from the perspective of lessons learned and details features planned to support the initial research efforts planned for 2000.

Four successful UCAV DMT demonstrations and experiments are presented from a lessons learned perspective. Starting with the initial separately developed PC-Based UCAV simulations; evolving to the merging of the simulations and initial DMT research experiments including DMTO&I testbed, I/ITSEC99 and planned AFRL Mesa UCAV DMT Demonstrations. Key testbed components included the LiteFlite Flight Simulator, JSAF and SOAR applications, and the Variable Autonomy Control System (VACS). The unique and innovative portions of this paper detail the components integration for UCAV missions and operational concepts, along with the human factors engineering on the VACS human-system interface design and LiteFlite researcher toolkit interfaces. Illustrative examples, are also included with sufficient details to support other government, industry and academic organizations participation in future UCAV DMT experiments and demonstrations.

Participating organizations include but are not limited to AFRL Mesa, SDS International, Geneva Aerospace, Eglin 46th Test Wing PRIMES, NASA Dryden Flight Research Center/Tuskegee University, Computer Science Corporation. Future participants may include Navy Pax River (MFS and Distributed Simulation Groups), AFRL Wright-Patterson and Naval Aerospace Medical Research Lab. Additional discussion includes related UCAV DMT Research topics of:

- LiteFlite UCAV and Testbed Utilization of the Ordnance Server to ensure DMT Fair Fight
- Innovations associated with a new Distributed Ordnance Server to insure Temporal Correlation of the Target/Counter-Measure/Weapon Triad
- An Innovative new concept of handing off UCAV Ownership from the Virtual LiteFlite Host Simulation to the Constructive JSAF and SOAR Agents to automate tasks for the UCAV operators

Results from three initial UCAV integration efforts are presented detailing DIS integration with existing DMT assets and HLA integration with planned DMT configurations I/ITSEC99, USAF Only DMTO&I Demonstration Jan2000, DMT UCAV Testbed development for AFRL/HEA and UAV 2000 Demonstration July 2000. An outline of planned research efforts that will utilize the DMT UCAV Testbed are presented along with Future Research Directions.

About the Authors

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Figure 1. UCAV over Nellis and Eglin (Actual Screen Shots)

OVERVIEW OF DMT UCAV TESTBED (DISTRIBUTED MISSION TRAINING)

The aim and opportunity of the DMT UCAV Testbed is providing researchers with a low-cost reconfigurable simulation environment which is interoperable with Distributed Mission Training resources. DMT and PC based components have evolved to where it is feasible for researchers to prototype, experiment, test new systems and new concepts within the DMT context. The Testbed presented in this paper was designed to maximize the advantages and benefits of a distributed architecture with innovative reuse of government owned components and DIS and HLA standards

within. Specifically, the development of the baseline DMT UCAV Testbed is discussed from a lessons learned and future challenges perspective with illustrative examples of the benefits and tradeoffs to both the simulation/training and test communities. One of the key imperatives is to provide the researchers with a realistic What-You-See-Is-What-You-Get (WYSIWYG) environment. Even though the Testbed is based upon Low-Cost PCs the imagery is Photo-realistic with Geo-Specific Terrain See Figure #1 above for an actual screen shot from the LiteFlite UCAV Reconfigurable Flight Simulator Component of the Testbed.

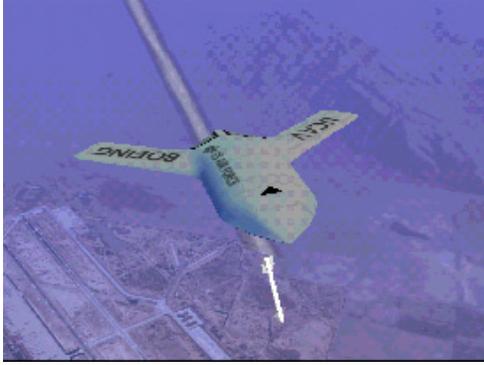


Figure 2. UCAV SEAD Mission (Actual Screen Shot)

The Testbed is a means of cooperative research, data exchange and common visualization is emphasized. The overarching DMT UCAV Testbed philosophy is the researchers develop in a common environment for the benefit of all. Consider the case of separate UCAV research centers all over the United States (and potentially an Australian site too) using the distributed features of the Testbed to cooperatively develop UCAV features. One illustrative example is the AFRL research group in Wright Patterson, developing the UCAV operator interfaces, while the AFRL/HEA Mesa group is investigating the effectiveness of those interfaces, while the Eglin 46th Test Wing investigates the Weaponization of the UCAV.

The UCAV DMT Testbed initial research will focus on technologies for:

- Defining effective training strategies for UAV/UCAV operators
- Assessing the delta in training required for multiple vehicles
- Advanced displays driven from human factors design
- Integration of Geneva Aerospace s Variable Autonomy Control System
- Integrating several UAV and UCAV Flight Model into the Testbed
- Direct linkage of UCAV Testbeds as Participants in DMT
- CONOPs comparison of smart UAVs working cooperatively with relatively dumb UCAVs utilized as GPS bomb haulers, vs the utilization of smart UCAVs
- Initial research into communication of AWACS controllers with UCAV operators and Flight Leads. Specifically, investigate value of including UCAV operators to manned aircraft communication.

Excluded from this paper are developments and extensions of the UCAV DMT Testbed for other UCAV research efforts into displays and Space Maneuver Vehicle Research which are still in negotiation or planning at the time of this paper submission (i.e., SMV is funded but still in contracting).



Figure 3. UCAV LiteFlite LCD Projector Demonstration I/ITSEC 99

Results from four initial UCAV integration efforts are presented detailing DIS integration with existing DMT assets and HLA integration with planned DMT configurations I/ITSEC99, USAF Only DMTO&I Demonstration Jan 2000 and the AFRL/HEA DMT UCAV Testbed.



Figure 4 LiteFlite DMT F-15 Configuration Demonstration I/ITSEC 99

The UCAV Testbed integration efforts are discussed from a context of components including:

- LiteFlite Reconfigurable Flight Simulator
- Variable Autonomy Control System
- SOAR Artificial Intelligent Constructive Simulation Agents & SOAR Speak
- JSAF
- Ordnance Sever (OS)

The key innovations actually added to the infrastructure and architecture of the Test bed are then presented with emphasis on:

- LiteFlite UCAV Utilization of the STOW Ordnance Server (OS) to ensure DMT Fair Fight and temporal correlation of the Target/Counter-Measure/Weapon Triad
- An innovative new concept of handing off UCAV Ownership from the Virtual LiteFlite Host Simulation to the Constructive JSAF and SOAR Agents to automate tasks for the UCAV operators

An outline of planned research efforts that will utilize the DMT UCAV Testbed are presented along with Future Research Directions.

UCAV Integration Efforts

The authors have participated in initial UCAV integration efforts together, Specifically, our initial two effort were in support of CSC DMTO&I Phase I contract to investigate DMT communication requirements and ensuring the DMT Fair Fight occurred.

DMTO&I Phase I Integration

The team utilized SDS s LiteFlite Reconfigurable Flight Simulator in a HLA mode with the Synthetic Theater of War (STOW) Tools including JSAF constructive simulation and synthetic environment, SOAR cognitive agents and SOAR-Speak operating as a Human Computer Interface (HCI) for dynamically controlling constructive agents. Multiple Virtual LiteFlites were flown in conjunction with the constructive entities in trails to develop and verify experimentally requirements and planned innovations. One such innovation was to use a constructive framework application to handle the missile fly-outs and kill assessment. The motivational rationale for this innovation was to provide a munitions standard for all the DMT participants to use. The LiteFlite missile model source code was recompiled into the constructive framework application and the effected LiteFlite modules altered to support issuing the fire command without flying-out the missile. The LiteFlite ownship damage assessment modules were left unchanged with the munitions server detonation data (e.g., munitions type, position, etc.) being read from

HLA or DIS PDUs and utilized for the damage assessment. The prototype munitions sever was utilized on the DMTO&I instead of the classified STOW OS due to schedule constraints and the open nature of the research environment. The unclassified nature was necessary as the Testbed was planned for two DMTO&I demonstrations one at IITSEC 99 where the munitions server would not be shown (competitive reasons) and the January USAF only demonstration where the munitions server would be demonstrated as a methodology for insuring fair fight.

One other clever innovation used in the first testbed was the utilization of multiple RTIs, including both the STOW RTI and the DMSO RTI via a DIS gateway. The constructive STOW entities from JSAF, and SOAR utilized the STOW RTI which was linked via a HLA to DIS Gateway. A second Gateway was used to interface to the DMSO RTI where the LiteFlite Entities and the other framework entities and stealths interoperated.

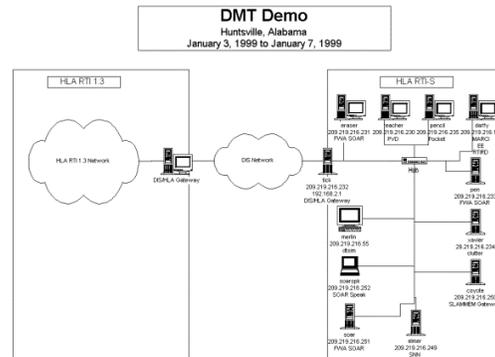


Figure 5. DMTO&I Testbed

DMT UCAV Testbed

Our third UCAV Testbed and most advanced integration prototypes were developed for AFRL/HEA explicitly for DMT UCAV Testbed. The DMT UCAV Testbed can operate in HLA or DIS with DIS was selected as the initial standard. All of the Testbed components were integrated at SDS s Orlando Location and AFRL at Mesa.

The Orlando Testbed components include 2 UCAV LiteFlites (one 8 channel and one two channel), JSAF, Unclassified Ordnance Server, SOAR, SOAR-Speak, ModIOS and SDS s ArchAngel XML Server.

The Mesa Testbed consists of 5 LiteFlite UCAVs and JSAAF. One of the LiteFLite Stations is configured with five monitors to operate 4 UCAVs from a Control Station GUI and Displays that were constructed to replicate the original work done by WPAFB Operator Vehicle Interface Lab. AFRL has three additional LiteFlite UCAVs and JSAF in the unclassified Testbed and has one UCAV LiteFlite in the DMT research facility already interfaced with the F-16s.

The UCAV PC linked in the DMT research facility has the dubious honor of being the first simulated UCAV to be killed by friendly fire by AFRL F-16 Simulations. This event happened during an integration test where simulated F-16 pilot Bart called to simulated UCAV operator Matt inquiring if his shields were up (Shields up is slang for simulations set to not die as a result of a weapon kill on ownship). Matt replied yes, however, upon missile impact this turned out to be incorrect. Hence the first simulation UCAV death in the Mesa DMT Prototype environment.



Figure 6. LiteFlite DMT 8 Channel Configuration Prototype

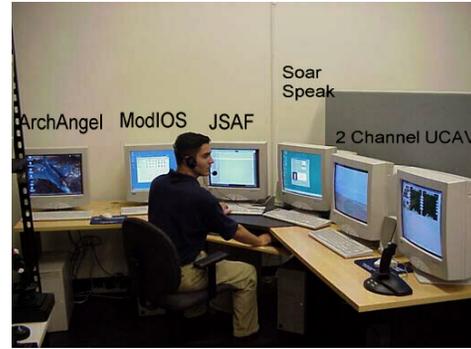


Figure 7. DMT UCAV Testbed (Orlando)

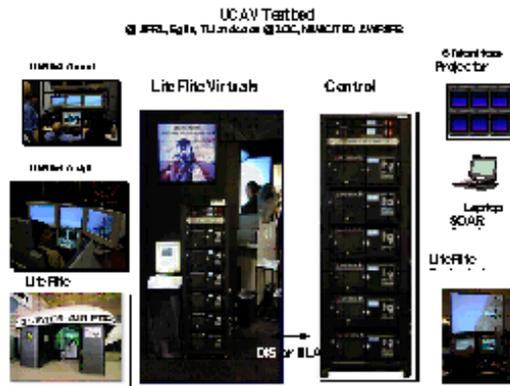


Figure 8. DMT UCAV Testbed Reconfiguration Display Options

The Testbed is designed to use low-cost PCs to support an entire range of control station and visual system solutions. Further the visual interface is also designed to interface to the SDS s AAcuity SB PC-IG products to allow visualization in M2DART type displays (<http://www.williams.af.mil/html/dmtvs.htm>). The next few figures show the different configurations envisioned for the Testbed utilization with both the training and test communities.

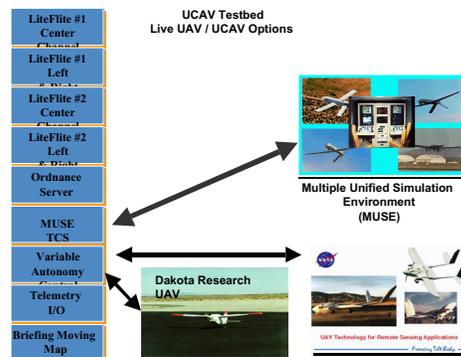


Figure 9. Live DMT UCAV Testbed Reconfiguration Options

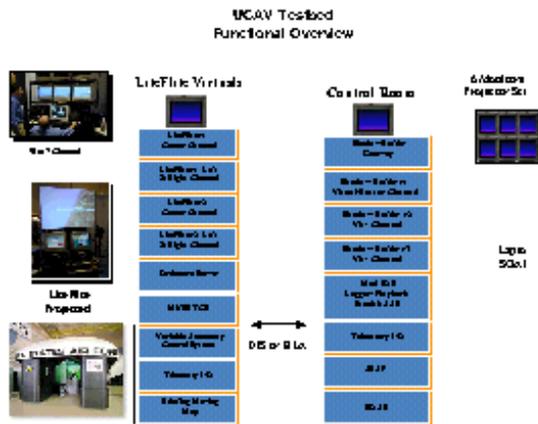


Figure 10. DMT Testbed Live Interface Options

UCAV Testbed Components

The UCAV Testbed integration efforts are discussed in this section from the context of components including:

LiteFlite™ Reconfigurable Flight Simulator

LiteFlite™ Reconfigurable Flight Simulator was designed as a Low-Cost PC-based simulation and training toolkit to support researchers efforts investigating aircrews training and practicing in individual and team training environments including local and long-haul networking. The baseline LiteFlite UCAV system uses a two-monitor configuration. One monitor displays the Out-The-Window (OTW) view, including Heads-Up Display (HUD) data, other aircraft and weapons effects visuals, and photo-realistic, geo-specific visual databases. The second monitor displays cockpit instrumentation, fully adaptable to support various aircraft types, crew positions, and radar functions. Multi-Channel Visuals (2-16 channels) and Virtual Reality Helmet Mounted Display (HMD) configurations are also available to provide greater flexibility to the OTW view. Systems include a fully capable PC-based Researcher / Instructor Operator Station (IOS) and either generic or aircraft-specific aero models. The LiteFlite™ UCAVs are designed to support both military and commercial networks IPX, Microsoft DirectPlay (modem support tool), UDP, DIS, and HLA.

SDS has partnered on several innovative research efforts aimed at utilizing LiteFlite combined with Distributed Mission Training (DMT) architecture to create a framework for the direct exchange of data and scenarios between training and test communities.

LiteFlite Features that support researchers reconfigurable requirements in the testbed include but are not limited to:

- LiteFlite Performance Measure Features were built with the design goals of allowing non-programmers to select:
 - Desired performance measures and the desired frequency of the measurements via an Excel Spreadsheet input format.
 - Desired performance measures and scored outputs in Excel readable format for direct use by statistical and analysis software tools.
 - Visual Basic Script to allow entry-level programmers to control the real-time scoring of performance measures without recompiling any of the LiteFlite Code. This innovation allows the Script to be read at initialization and researchers to change the real-time scoring in the simple script file. (Note: These first three features were originally built-in to LiteFlite for cooperative research of PC-Based Pilot Self Instructional Technology Research sponsored by AFRL/HEA s Dr. Peter Crane and NASA Dryden Flight Research Center.)
- Simple Editable Text Files for altering parameterized configuration files for altering existing aircraft and adding new Aircraft. For example, to add an experimental F-22 with bigger engines only four lines of text need to be added: a line to use F-22 and three lines to alter thrust and weight characteristics. Response lag and other features can also be overwritten too, but this example is presented for a simple case.
- Reconfigurable Instruments from Text Files the Instrument Description Files *.idf can be altered for state information, position and size again by a researcher without programming skills.
- DISTI s GL-Studio compatibly, planned option for allowing GL-Studio Instruments to be directly imported into LiteFlite.
- Head Tracking, EyeTracking and Physiological Measures correlated with DIS Log files and timestamps for Naval AeroSpace Medical Research Lab (NAMRL) research innovations and accident recreation features.
- Different Levels of Flight Models from the non-linear parameterized model to a wind tunnel model and use of the Variable Autonomy Control System (VACS) (See next section for VACS details)
- LiteFlite was altered from a single aircraft control station using stick and throttle to an automated 4 ship controller replicating the Situational / MFD Display replicate based upon the original interface developed by WPAFB Operator Vehicle Interface Lab. See figure11.

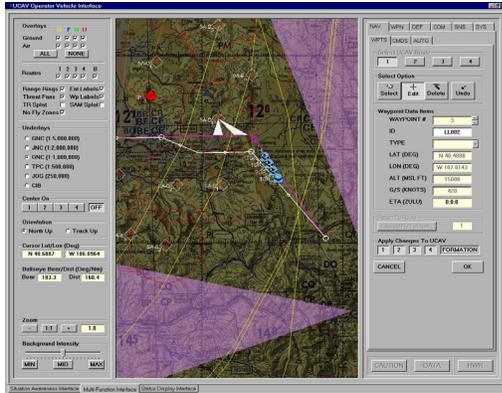


Figure 11. LiteFlite UCAV Situational/ MFD Display replicate based upon the original interface developed by WPAFB Operator Vehicle Interface Lab.

It is important to note that the LiteFlite image above was developed based upon JPEG images from AFRL/HECP Operator Vehicle Interface (OVI) Group. The key to economically supporting the UCAV researchers is effective rapid prototyping. To this end SDS with their DISTI team partner were able to develop the Situational Display and the major portions of the Multifunction Display to functional prototype level including the DIS connectivity in less than 120 Hours. (See figure 11 above for the prototype UCAV Multifunction Display.)

Variable Autonomy Control System (VACS)

As a portion of the DMT UCAV Testbed development, the Geneva AeroSpace Variable Autonomy Control System (VACS) was added to LiteFlite. The VACS is designed to be effective for UAV and UCAV systems as usable to individuals whose training is focused on the requirements of a given mission or the usability of the payload, rather than on the aviation of the vehicle. As the dependence on UAVs for military operations grows and UAV technology is integrated into the emerging global command and control architecture, the cost and complexity of managing and controlling these assets can easily become substantial. The VACS solution to this UAV control problem lies in the appropriate functional allocation between the human and the machine. By merging modern stand-off missile flight control, advanced aircraft flight control, and state-of-the-art communications technologies, Geneva has developed a novel hierarchical flight control structure with varied levels of remote operator input to address the human-machine functional allocation problem.

The VACS has been successfully demonstrated enabling a diverse range of users to effectively operate UAVs. Furthermore, the VACS solution eliminates the requirement for UAVs to be controlled by highly

trained, rated pilots. In a continuing development and demonstration effort VACS is to be used Joint STARS MTE workstation and the Freewing Scorpion 100-50 UAV and conduct a flight test demonstration. This program will demonstrate the benefits of the variable autonomy flight control system design with simplified manual control modes, demonstrate the compatibility of such a system with the military's emerging C⁴I architecture, and demonstrate the synergism between Joint STARS and UAVs using the simplified UAV flight control technology.

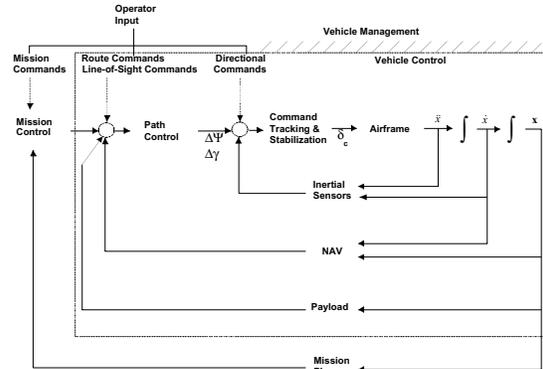


Figure 12. Variable Autonomy Control System (VACS)

JSAF, SOAR & SOAR Speak

Current distributive training technology has evolved towards larger Federations and greater entity resolution. DARPA's STOW has been the only demonstrated large-scale High Level Architecture (HLA) simulation using both large aggregates (for visualization) and entity resolution (for interaction arbitration). Since the October 1997 DoD Advanced Concept Technology Demonstration (ACTD) milestone, STOW has evolved to a viable technology demonstrating high resolution (platform level) simulation to support joint command and staff training, mission visualization capabilities and unit level training. STOW's ability for entity-level resolution has made it an excellent candidate for the USAF Distributed Mission Training (DMT) Program. The STOW Program has evolved into the Joint Semi Autonomous Forces (JSAF) and increased its applications to provide a robust simulation capable of supporting operational training, testing new concepts and doctrine as well as service and joint experimentation issues with direct linkages to real-world C⁴ISR systems in a seamless live, virtual or constructive environment. The current JSAF sponsor is the United States Joint Forces Command (USJFCOM).

The STOW Program was created within the DARPA Advanced Distributed Simulation Program as a result of the recognition that the capability for high fidelity distributed simulation (live, virtual and constructive) offered great potential for training joint forces and for a variety of other DOD uses. The program was based on work then being done at DARPA on synthetic forces and synthetic environments and earlier efforts with the US Army on the SIMNET virtual trainers. JSAF provides simulation of a joint synthetic battlespace. The key elements of STOW are the Synthetic Natural Environment (SNE), Synthetic Forces and Command Forces. The SNE features high-resolution terrain databases, dynamic terrain and objects and a meteorology and ocean server. Synthetic Forces simulate all the platforms and entities in the synthetic battlespace, incorporating individual and unit behaviors.

HLA provides a specification for common architecture and structural basis for simulation interoperability. The HLA environment allows for a common boilerplate for supporting reuse and simulation interoperation across the Department of Defense. HLA was developed on the premise that no one simulation can meet the diverse demands or requirements for all Service and Joint Components. However, having a common architecture where all users can tie-in allows for a greater interaction among federates and provides the common environment for reuse. These users can develop specific simulation federates to meet their needs as the rules established in the HLA baseline definitions for both time management and data distribution management. STOW was the first exercise to use routing spaces and Data Distribution Management (DDM). The HLA DDM is used to specify which federates receive messages for each update and interaction. The Run-Time Infrastructure (RTI) uses information provided in publish/subscribe calls to set up filters that direct data among federates that need them. The RTI provides the mutual communications link used by all exercise/experiment players. Subscription to the amount of information needed to do the job reduced traffic over the lines and allowed for more players to be present in the battlespace without impacting the resolution capability. A key result of DDM is the ability to employ PC-class workstations with no decrease in interaction validity. Improvements in PC performance only reap greater simulation performance with increased computer memory and speed. JSAF currently uses RTI-S and has migrated to DMSO RTI 1.3NG.

The JSAF advances in a large curved earth dynamic terrain database and its dynamic weather built a great foundation towards increased realism in virtual and

constructive simulation. These added benefits allow training audiences to see the effects of poor weather on target acquisition and make real-time targeting decisions for follow-on Air Tasking Orders (ATOs). Once the new ATOs or ATO changes are distributed, then the JSAF constructive simulation re-attacks the targets. These features coupled with an accurate Bomb Damage Assessment (BDA) capability allow for interplay with the Intelligence and Combat Plans communities.

JSAF uses a large-scale dynamic synthetic natural environment (SNE) with a pre-distributed terrain database (TDB) with real-time distribution of the battlefield environmental effects and dynamic changes to the terrain and cultural features. SNE digital terrain features include 3-D representation of cities and other manmade objects such as bridges, pipelines, and roads based on comprehensive mapping and analysis of the urban areas to intermingle with cultural features of military significance. Source data for the TDB is the National Imagery and Mapping Agency (NIMA) with digital elevation models for terrain surface and ocean bathymetrics, 10 meter resolution satellite imagery, numerous digital feature data sets, digitized maps, and paper maps with scales as large as 1:12,500. Numerous TDBs are available from Southwest USA to Europe and the Mediterranean Sea, Southwest Asia and the Far East and Korea. An interactive TDB showing defensive positions, emplacements, and associated weapons acquisition and effects is key to construct "what if" scenarios for new weapons platforms, sensors, and individual weapons.

JSAF, through the TacAir Soar program, uses Artificial Intelligence (AI) in constructive agents. These Soar agents, using approximately 6000 rule-based architecture, fly formation, engage targets and return-to-base at appropriate times for mission execution all the while responding to the battlefield dynamics. The rule sets in Soar follow current tactics and service doctrine. Soar agents fly their missions without any intervention from operators behind the scenes greatly reducing the numbers of operators needed for the exercise execution.

AirSF and TacAir-Soar are respectively the physical system and cognitive components of the air portion of the JSAF system. JSAF also includes naval, ground maneuver, amphibious, Opposing Forces (OPFOR), and other constructive simulation representations (computer generated forces) that are fully interoperable with one another. JSAF entities interact in the most sophisticated synthetic environment (atmosphere, terrain, ocean) currently available. AirSF provides a set of common physical system models such as flight

dynamics, airframe, sensors, and communications, to name just several, that are data driven and can be parameterized to represent a variety of U.S., coalition, threat, and civilian aircraft. Intelligent aircrew agents which are capable of performing a variety of doctrinal missions (OCA, DCA, CAS, strike, interdiction, etc.) are modeled using the Soar AI application language. Soar has several distinct advantages that apply to modeling human performance in a very complex task domain such as air combat. Some of these advantages compared to other threat system generators include:

- Ability to achieve multiple "skill levels" based on performance variables covering the entire spectrum of:
 - a) Platform sensors use (ability to use Fire Control System to full fidelity based on experience levels) as well as proper use and interpretation of RWR inputs
 - b) Weapons employment (function of shots available based on varied weapons selections, percent of max range, ID criteria, and FCS/visual cueing).
- The Soar language is a true model of human cognition and not an expert system or if/then finite state machine. Soar models short-term memory and perception (situation awareness), long-term memory (tactics, techniques, procedures), and the capability to learn through experience. (At this time learning is not activated for AirSF/Soar.)
- Because a rete matching algorithm is used, Soar performance is independent of the total number of rules used to represent mission behavior. The rete algorithm precompiles the rules into a network, then as new data comes it traverses this network to see which rules might match the new data. Only those rules, which are potentially applicable, are considered. The bottom line is that the times required for a match is pretty much constant no matter how many rules are added.
- Soar aircrew agents communicate with one another and with human participants in a simulation exercise through use of either understandable military directives or the Command and Control Simulation Interface Language (CCSIL). Messages are used to convey both voice and digital communication messages between Soar aircraft and their controlling agencies which can include at this time either human controllers or Soar agent forward air controllers and air controllers. This capability includes inter-aircraft tactical communications for combat formation flight, air combat intercepts, and CIC maneuvering.

- Soar aircrew agents operate as multi-aircraft, 2-ship, and 4-ship units that can be integrated to form large strike packages with varied aircraft types performing different but complementary missions in the same manner as for live air operations.
- During mission execution each Soar aircraft outputs a list of current goals and actions, and may be queried for the reasons for the actions that specifically describe the when/how/why behind the decisions made that affect mission performance. This capability should be considered a hard requirement for any computer generated force used for DMT as it allows the mission behaviors to be validated for the intended purpose of DMT in accordance with USAF VV&A policies. This capability has been further extended with graphical tools that show the current situational awareness of any entity.
- Soar mission execution is fully automated and does not require any manual intervention except to retask a mission through simulated command and control channels. An instructor to modify mission execution to achieve training objectives can also use this capability.
- Soar agents operate as Mission Commanders, Four-Ship Flight leaders, Element Leaders, and Wingmen including inter-aircraft communications for tactical operations including a very robust capability to fly tactical formations (tactical turns, in place turns, cross turns, etc.) while patrolling and during air combat intercepts. In the event of loss of lead, the aircraft are able to adjust their formations and determine a new lead.

JSAF's object based modeling allows greater flexibility and ease to create modifications. Its modular and composable architecture provides the Plug-and Play aspect needed to evaluate new systems to conduct "What-If" iterations in the joint synthetic battlespace. Basically, if the model physical attributes (data) are provided, then adaptations can be made and easily integrated. During the Joint Warfighter Experiment 99 (JWE-99) development, software engineers and subject matter experts (SMEs) adapted JSAF for a 2015 time critical target scenario using future sensors and weapons. Object oriented modeling permits the user to modify known platforms or models with attributes of another provided the same interactions are used. For example, Object 1 has attribute A and B; Object 2 has attribute C and D. With object oriented modeling, Object 2 can be modified to have a hybrid of both objects' capabilities. Basically, an interchange of existing systems can be placed on various platforms to determine its survivability or whether it makes a difference in the way the operation is conducted or in

its effectiveness within the same engagement parameters as before. STOW produces stochastic results during the simulation execution. Of course, that is not to say it cannot be deterministic. In fact, if all variables remain constant, then the outcomes will be very deterministic. Given enough stochastic runs, you can achieve a high degree of confidence intervals to bound conclusions while operating in the battlespace.

KEY FEATURES AND BENEFITS OF THE DMT UCAV TESTBED

There are a great number of obvious standards benefits and interoperability to a DIS and HLA battlespace environment that are well documented in the numerous publications (<http://www.dmsomil>). Two new innovations are planned for the DMT UCAV Testbed infrastructure that will have far reaching benefits for both the training and test communities. Specifically, the innovations are:

- LiteFlite UCAV Utilization of an Unclassified Distributed STOW Ordnance Server to ensure DMT Fair Fight and temporal correlation of the Target/Counter-Measure/Weapon Triad
- An innovative new concept of handing off UCAV Ownership from the Virtual LiteFlite Host Simulation to the Constructive JSAF and SOAR Agents to automate tasks for the UCAV operators

UCAV Utilization Of An Unclassified Distributed Stow Ordnance Server

The authors are planning on presenting another I/ITSEC 2000 paper titled DMT Fair Fight Temporal Triad: Weapon, Counter-Measures, Target via Distributed Ordnance Servers that details the advantages of Distributed Ordnance Servers. For the purposes of this paper only a high level solutions will be presented to critical problems associated with the DMT simulated kill inaccuracies that can occur due to network latencies. McKee (1997/98) utilized live fire criteria as a basis for DMT type testing with live and constructive models and found latencies of greater than 70ms too great for weapon use against a maneuvering target. The unique and innovative portion of this paper is by architecturally adding distributed ordnance servers and transfer of ownership of weapons between Ordnance Servers latencies of greater than 70ms can still accurately model fair fight outcomes.

The I/ITSEC 2000 paper includes extensive background discussions of Physics Latency Constraints with Illustrative Examples (DMT and DIS/HLA); Prior Solution Attempts-Prediction/Roll-Back Solutions, Monte Carlo; Solution restrictions, as well as initial Ordnance Server Improvements, and proposed Transfer of Ownership hypothesis.

The key hypothesis investigated is, Fair Fight can be achieved insuring the weapon model, the target model and any countermeasure models operate in the same temporal space. (local Distributed Ordnance Server.) The new phase Temporal Triad was coined to describe these interactions.

Of particular use to the simulation and training communities are graphics and models that illustrate Network Induced latency of greater than 70ms weapon to target is too great for fair fight against maneuvering targets: 1) The Graph of kill accuracy as a function of induced latency. 2) Graph of success with multiple distributed Ordnance servers each flying the weapon into its respective local target aircraft in the face of Counter Measures. It is envisioned that this type of accuracy will be of high value during research of UCAV SEAD operations.

UCAV Testbed Integration Of Virtual And Constructive Simulations For Automation Research.

The authors new concept of handing off UCAV Ownership from the Virtual LiteFlite Host Simulation to the Constructive JSAF and SOAR Agents to automate tasks for the UCAV operators. Example SEAD Task:

- UCAV Operator utilizes an aggregate feature to select two UCAVs as a group.
- UCAV Operator designates a group to attack a SAM site using wild weasel tactics .
- LiteFlite Simulation hands off ownership of the two tasked UCAVs to JSAF/Soar.
- JSAF/SOAR flies the UCAVs against the SAM site using the sophisticated behaviors already built-in.
- JSAF/SOAR controlled UCAVs kill SAM, re-attack if necessary, does damage assessment, determines attrition of UCAVs (losses & damage that occur).
- JSAF/SOAR returns control of the UCAVs to LiteFlite either by having them proceed to the next waypoint scheduled or a parking orbit with a notification back to the UCAV operator to assume control when ready.

This blending of Virtual and Constructive simulation will support investigation into the different levels of automation without requiring the expenditure of funds to develop new behavior frameworks within the host virtual simulation. Even if a behavior does not already exist in JSAF or SOAR the cost of adding the behavior to their existing framework is much less and reusable.

Investigation of communication effectiveness of various command and control alternatives for UCAV

operators. For example, UCAV operators could have their Air Tasking Order Assignments and be issued real-time targeting updates and modification of plans by AWACS controllers verbally. Given the larger network communication the AWACS or JSTARS can send a portion of their graphic display center on the UCAV area of interest with the target(s) designated with an overlay for the UCAV operators. Or is performance superior when a Flight Lead communicates directly to the UCAV operator as another peer Flight Lead. Specifically, investigate relative merits and tradeoffs of including UCAV operators to manned aircraft communication at different levels, types and frequency.

- CONOPs comparison of smart UAVs working cooperatively with relatively "dumb" UCAVs utilized as GPS bomb haulers, vs the utilization of smart UCAVs
- Armed Predator and Laser Designator simulation experiments as fore-runners, to some of the planned flight test demonstrations for 4th Qtr 2000.
- Investigations as planned by AFRL/HEA

DMT UCAV TESTBED -- OUTLINE OF PLANNED RESEARCH EFFORTS AND FUTURE RESEARCH DIRECTIONS

The DMT UCAV Testbed is planned for use with multiple program including but not limited to:

- Multiple UAV/UCAV Research Projects
- Eglin 46th Test Wing UAV & UCAV Weaponization Projects
- Space Maneuver Vehicle Projects
- NAWC/TSD s Intelligent Tutoring System
- ArchAngel Real-Time Integrated Planner Player
- Potential Use with the MUSE TCS



SMV

