SYNTHETIC VISION SOLUTIONS:
OPERATIONAL SYSTEMS ASSIMILATION OF SIMULATION, LESSONS LEARNED AND CHALLENGES

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Abstract
Synthetic Visual System prototypes are demonstrating great promise for increasing aircraft safety, increasing situational awareness and providing advanced steering cues in operational aircraft. Synthetic Vision enhancements are the beginning of a new wave of integration of simulation into operational equipment that will have far reaching benefits for both the operational and simulator communities. Specifically, the rapidity of the initial research imply that Synthetic Vision systems and associated simulation components may find near term application into operational systems. This paper presents representative examples of current synthetic vision research projects in the context of lessons learned and posits challenges to the simulation and operational communities to develop Synthetic Vision near term benefits for military and civilian systems.

An introductory Synthetic Vision example is given as a detailed description of how the authors plan to build a portable synthetic vision display with weather, terrain, and warning cues for vehicles by combining COTS components The discussion emphasizes the further advances made possible from baseline operational systems with GPS and Synthetic Vision. The advances detailed include the unique innovation of adding an advanced simulator as an active component of actual operational equipment. Such an approach is a revolutionary concept that has far reaching benefits. The addition of existing simulators as an additional active component to existing operational systems permits addition of advanced features at a fraction of the cost vs. conventional methods

A Synthetic Vision categorizations framework is suggested from basic low-cost "miss the mountain viewer" type applications to advanced multi-spectral displays for actual mission employment. A narrative description precedes the framework exploring characteristics, parameters and attributes associated with each category. An example of the framework applied to an existing Synthetic Vision prototype is presented. Three Synthetic Vision projects lessons learned, advantages, disadvantages and challenges are presented in summary format.

The challenges of a planned implementation a synthetic vision system on UAV ground control stations for NASA and USAF programs are discussed. The planned introduction of a four channel PC based reconfigurable simulator into UAV ground control stations are presented as an illustrative example. Planned benefits include:
- Geo-specific photo-textured Out-The-Window imagery on 4 channels to enhance situational awareness via a wider field of view and increase safety as weather obscuration nor night conditions will effect the correlated simulated visuals
- Super HUD -- Target Designators and Ground WayPoint Designators will appear over all four OTW screens
- Terrain Avoidance – A reconfigurable flight simulator adding F-16 HUD, Warnings and Instruments will be demonstrated as new capacities that the Predator Ground Control Stations can add.
- 360 degree high fidelity visibility option based upon a 6 channel PC-IG driving the USAF M2DART Display

Synthetic Vision and the melding of simulators as functioning components of operational equipment are challenges for the 21st Century. This paper hopes to serve as a catalyst to advancing simulation into this new frontier.

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INTRODUCTION: OPERATIONAL ASSIMILATION OF SIMULATION

Synthetic Visual System prototypes are demonstrating great promise for increasing aircraft safety, increasing situational awareness and providing advanced steering cues in operational aircraft. Synthetic Vision is best defined and characterized by the NASA original document "Research, Development, Prototyping , and Implementation of Synthetic Vision Information Systems" (NASA 1998) excerpted below:

"NASA is soliciting proposals for research, development, prototyping, and implementation of Synthetic Vision information systems and topical areas that have the potential to contribute to a reduction in the rate of fatal aviation accidents. Synthetic Vision systems are intended to reduce accidents by improving a pilot's situational and spatial awareness during low visibility conditions, including night and Instrument Meteorological Condition (IMC). The types of accidents expected to be most effected by synthetic vision technologies include Controlled Flight Into Terrain (CFIT), Loss of Control, Runway Incursion Accidents. Aircraft categories covered by this announcement include low-end general aviation aircraft, high-end general aviation aircraft (business jets), and commercial transports. Proposals addressing rotorcraft-specific issues will also be considered as a part of the low-end thrust.

This effort is part of the NASA Aviation Safety Program (AvSP) and attempts to follow the Weather Investment Recommendations Summary of the weather sub-team of the Aviation Safety Investment Strategy Team (ASIST) as publicized on the Internet… The effort will emphasize the cost-effective use of synthetic/enhanced vision displays, worldwide navigation, terrain, obstruction, and airport databases, and Global Positioning System (GPS)-driven navigation to eliminate "visibility-induced" (lack of visibility) errors for all aircraft."

NASA concepts for Synthetic Vision are laudable, however, the authors would like to expand the definition by including Ground Control Stations for remote piloted craft including existing Unmanned Aerial Vehicles (UAVs) and planned Unmanned Combat Aerial Vehicles (UCAVs). Since, no human lives are at risk the UAV and UCAV test environment will allow researcher to push the envelope of Synthetic Vision research early and more aggressively. The authors also urge that Synthetic Vision be considered in the macro context of simulations being integrated directly into operational equipment. The distinction between simulation and real world has become so blurred that only ingrained outdated concepts stop the simulation and operational communities from fusing to the benefit of all. Synthetic Vision enhancements are the beginning of a new wave of integration of simulation into operational equipment that will have far reaching benefits for both the operational and simulator communities. Consider Synthetic Vision as part of continuous development of Toffler's Third Wave concept of info-sphere and simulation integration (Toffler 1980, Guckenberger 1997). Synthetic Vision fits the Third Wave model providing customized, just-in-time data and images to the users. Even the software design tools and languages are pushing to synergy between the operational and simulation communities. Witness the Unified Modeling Language (UML) as a common language that software developers are adopting regardless of their operational or simulation affiliation (Muller 1997) . It is beyond the scope of this paper to expound the detail of the Third Wave concepts but the authors strongly encourage others to use the Third Wave as framework and a background to consider developing technologies such as Synthetic Vision.

The rapidity of the initial successes imply that Synthetic Vision systems and associated simulation components may find near term application into operational systems(Alter et al 1999, Kruk et al 1999). This paper presents representative examples of current synthetic vision research projects in the context of lessons learned and posits challenges to the simulation and operational communities to develop near term benefits for military and civilian systems.

Introductory Synthetic Vision Example

Guardian Angel is a portable Synthetic Vision display that has been proposed to NASA. The phased construction of the Guardian Angel Prototype is utilized as an introductory example to outline the simple method of integrating existing technology to realize the benefits of Synthetic Vision. The three phases are: 1) Near Real-Time Weather, 2) 3D Synthetic Terrain View, 3) Advanced Terrain Avoidance and Navigation cues and warnings. Each of the phases will be outlined in the context of adding progressive features to such a Guardian Angel Synthetic Vision Display.

Weather Synthetic Vision

Near Real-Time Weather can be added to existing cockpits (e.g., boats, ships, and land vehicles too) by adding a PC with GPS accessory, modem, satellite phone and an internet browser set to one of the many satellite image weather sites. The latest Internet satellite weather photographs are down loaded and zoomed to ownship position updates from the GPS (See http://www.ghcc.msfc.nasa.gov/cgi-bin/post-goes) for strategic 2D overviews. Such a gross approach requires the pilot to interpret where his ownship is in the image. Adding a simple Java or C++ program that interpolates ownship position and orientation and places an overlay graphic icon of ownship in the 2D weather image from the GPS data increases the usability of our initial Synthetic Vision Display. The gross scale provides a strategic tool for in-flight navigation (e.g., re-planning).

The next feature to add is a local vicinity detailed tactical view utilizing Doppler 2D overviews and 2½D perspective images from Baron Services (Guckenberger 1999). Baron services provided Doppler Radar imaging Web Site for TV and Weather Stations for the US and overseas. 2D overview situational awareness is provided by utilizing the GPS to select the ownship grid, zooming to the pilots selection and interpolation of the image coordinates to place an overlay icon of the ownship position and orientation on the weather. The 2½D view can be rotated so that the GPS data can be used to display the ownship position from the actual vehicle perspective. That is the Field of View from the Synthetic Vision display will approximately match the pilots Out-The-Window view. Such an approach should allow the pilot to correlate the two images and navigate through the weather with better situational awareness and knowledge of expected outcomes. Further, additional information like storm severity, lighting strikes and winds can be selected to present a more complete picture to the pilot. Proper Human Factors research

should be done to determine what information is of value so as to not overload or distract the pilot.

The next feature to add is 911 and reverse 911 services. As part of a national air traffic control system a system like the proposed Guardian Angel system would allow pilots to use the active internet connection to hit a 911 button that would send his ownship information to a central aerial crisis manager. The manager's multi-monitor synthetic vision displays would mirror the situation of the pilot calling for help. The manager could help pick divert fields, select the best route out of trouble, or serve as the "just-in-time co-pilot" to assist in solving the crisis. By monitoring aircraft locations from that same internet connection, managers could send messages and advisories to planes en route. For example a reverse 911 call could br where the crisis manager breaks into the display, warning a pilot he is headed for bad weather and suggest a course around it.

Terrain Synthetic Vision

Synthetic Terrain is added to the Synthetic Vision Display by utilizing the GPS information to control the eye-point of a simulated ownship as it moves through a simulated 3D terrain. The terrain can be a simple grid of shaded polygons displayed from DTED data (Alter 1999) or photo-realistic aerial imagery integrated with DTED data (Guckenberger 1999) with addition of a 3D graphics board. The GPS updates are not frequent enough to supply frame by frame update rates at 30Hz or 60Hz so standard simulation dead-reckoning is utilized to supply the interpolated updates (IEEE 1278 DIS Dead-Reckoning and Smoothing Algorithms) Zoom and rotation are also supportable again with proper Human Factors research to aid the pilot and not confuse him. The Terrain environmental view could be set for perfect lighting conditions with no haze, or fog to improve pilot awareness. Further the 3D view can also be moved along the flight path for mission preview (Guckenberger 1995).

Advance Terrain Avoidance and Navigational Synthetic Vision

Advance Terrain Avoidance and Navigational Synthetic Vision is added to the Synthetic Vision Display by integrating a simulated F-16 avionics and HUD display. Way-point markers and terrain avoidance cues can be driven from the ownship information. (Guckenberger 1999). Additional features such s Highway in the Sky guide boxes can also be overlaid (Alter 1999)

Helicopter Displays are being augmented with Synthetic Vision displays in similar fashion by Kruk (Kruk 1999)

These advanced features are made possible from the baseline of operational systems with GPS and Synthetic Vision. The lesson learned is that the unique innovation of adding advanced simulator components as an active component of actual operational equipment permits addition of advanced features at a fraction of the cost vs conventional methods.. The prototypes can be viewed as a first steps in applying these revolutionary concept to existing operational systems (Civilian Aircraft Alter 1999, Helicopters Kruk 1999, UAV Ground Control stations Guckenberger 1999). The following section attempt to add a framework to describe and discuss Synthetic Vision Systems as a class.

SYNTHETIC VISION CATEGORIZATION FRAMEWORK

A Synthetic Vision categorizations framework is suggested below from basic low-cost "miss the mountain viewer" type applications to advanced multi-spectral displays for actual mission employment. The framework is suggested as a first draft upon which the simulation and operational communities can build upon. This draft framework is an attempt to standardize the characteristics and attributes to support communication and development of Synthetic Vision Systems. (See Table 1)

Category /Characteristic	Attributes / Parameters
Cost	Low defined as less the $20K, Medium as $20K to $100K and High defined as greater than $100K
Type	Portable, Appended, or Embedded
Map Support	Yes, No, Types of Map Formats supported, colors, update rate, minimum resolution of maps
Weather Display Support	Yes, No, Types of Formats supported, colors, update rate, minimum resolution of image features, view support (2D, 2½D, 3D), graphic overlays supported (storm intensity, Doppler, water content, lighting activity, etc…)
Terrain Display Support	Yes, No, Types of Terrain Formats supported, colors, update rate, minimum resolution of image features, view support (2D, 2½D, 3D), graphics supported (flat, Gourad or Phong shaded, photo-textured, or photo-imagery based)
Terrain Avoidance Cues	Yes, No, HUD Support (Pitch Ladder, Terrain X, Flashing Pull-Up warning) Verbal Warnings and Audio Tones,
Navigational Cues	Yes, No Military or Civilian Style way-point Markers, Highway in the Sky, etc…
Enhanced Sensors	Yes, No, Overlays or Image enhancements
Sensor Fusion Support	Yes, No, Description of which Sensor images are fused
911 Support	Yes, No, Description of the communication link, required crisis management center equipment, and if reverse 911 services can be supported
Network Support	Yes, No, GPS, Time Domain, Satellite Phone, Radio link, other
Certified by	FAA, Military, other

Table 1 Synthetic Vision Categorization Framework

For example, applying the framework to the FAA funded study (Alter 1999) that has already demonstrated a private civilian aircraft with a PC and differential GPS can constantly display the 3D terrain with HUD "Highway in the Sky" cues and sophisticated graphics flying curvilinear approaches into Juno Alaska would be characterized as a Synthetic Vision System that is Low-Cost, Appended, with Terrain (with Open-Flight Format, 22 bit effective color, 30Hz-60Hz update rate, 3D view , shaded polygons) with Navigational Cues, Differential GPS network support, and an uncertified prototype.

Synthetic Vision Lessons Learned, Advantages, Disadvantages and Challenges

Three Synthetic Vision projects lessons learned, advantages, disadvantages and challenges are presented in outline format with direct excerpts that highlight Synthetic Vision concepts are presented:

Civilian General Aviation Experiment (Alter 1999)
"Synthetic Vision with "pathway-in-the sky" display allows pilots to fly complex curved terminal area trajectories and could improve flight safety and flexibility"

"A perspective display as described in this paper would be well complemented with a map display or other strategic flight display which provides intuitive route/navigation information and terrain information 360 degrees about the airplane and about the planned flight path"

"Information displayed on the 3D pathway-in-the-sky/terrain display provides excellent course guidance and terrain awareness in the area in front of the airplane."

Helicopter Aviation prototype(Kruk 1999)

"Studies have been conducted on the UTIAS FFS using a database of the selected test site area (Gatineau Hills near Ottawa) derived from DMA data (8). Operational SAR pilots flew the simulator in representative scenarios with the database displayed in a version with the maximum level of detail available from the simulator image generation system (eg. trees, forest canopy, cultural features such as roads, buildings, etc.); and a version with the terrain simply covered with a checkerboard texture pattern and with major lakes and rivers represented to provide navigational references. Performance was actually superior with the less detailed scene as the geometric characteristics of the texture pattern aided in recognition of primary terrain features such as ridges, which may be camouflaged by the forest in naturalistic scenes."

UAV / UCAV prototype(Guckenberger 1999)

"UAVs and UCAVs ground control stations that include Synthetic Vision (SV) can increase the quality of operational missions and enhance the Situational Awareness of ground control personnel. This utilization of Synthetic Vision in the Ground Control Station context is the beginning of a new wave of integration of simulation into operational equipment that will have far reaching benefits for both the operational and simulator communities (Guckenberger 1999). Key innovations include terrain avoidance and advanced navigational cues being provided in addition to the Synthetic Vision display of correlated photo-realistic terrain for controller visualization. This paper presents initial research evidence and an associated demonstration that a PC-based Synthetic Vision display prototype—using a wide Field-Of-View (FOV) provided by multiple monitors run from a single PC enhances operator Situational Awareness and increases UAV ease of use. Further, the correlated photo-textured visuals are combined with F-16 type terrain avoidance and navigational cues/warnings not available in current ground stations. Future planned research on Synthetic Vision applications with NASA Dryden Flight Research Center and the USAF Air Force Research Laboratory, Human Effectiveness Directorate are presented."

"First Generation UAV Visual Systems suffered from many of the same problems as simulators with single screen Out-The-Window (OTW) visuals. The restricted FOV significantly increases the controller's workload and adversely effects the actual operational utilization of the UAV. A single video monitor causes even simple tasks such as turning into a landing pattern to become a difficult piloting task. The resultant maneuvering difficulty is high enough that it restricts actual operational usage to limited turns and long, straight-in approaches to landing. The obvious answer is to provide UAV and UCAV controllers with wider FOVs provided by additional cameras onboard the vehicle itself that down-link real-time video information to the controller station. However, this does not represent a viable solution due to constraints on vehicle payload, costs and, most importantly, video transmission bandwidth restrictions. The key innovation this paper suggests is providing the desired wider FOV via Synthetic Vision displays that augment the real-world video and sensor feeds, thus providing needed FOV while circumventing payload and bandwidth limitations. Specifically, correlated, photo-realistic 3D terrains can be presented on multiple monitors to aid controllers in orientation and Situational Awareness. The mission profile of UAVs may be best served by an arrangement of additional monitors or flat panels that flank either side of the central front viewing camera, and a row of additional monitors underneath"

UAV GROUND CONTROL STATION WITH SYNTHETIC VISION ENHANCEMENT ILLUSTRATIVE EXAMPLE

The cost of adding the additional 6 synthetic vision monitors to a ground control station is less than $10,000. Two PCs each with three 3D graphics boards provide sufficient processing power and drawing speed to support this type of application. In fact, UAV/UCAV Synthetic Vision prototypes were build to support just such a configuration and allow testing of the concepts. It is important to note that, PCs with up to four graphics boards each can be configured to support four OTW displays (one per graphics board) plus an instrument clusters on an individual basis. It is suggested that in the limited space confines of a ground controller station, no more than two PCs with three 3D graphics boards each be used to drive the 6 OTW displays. This approach also has the side benefit of reduced power consumption requirements. However, the ability to move to a single graphics board per PC is

available to increase performance should it be necessary on a particularly graphically intense terrain database. This expandability is a key feature of the reconfigurable software solution being provided."

If the Gentle Reader wishes to test the validity of the wider FOV assertion, one has only to fly a multi-channel flight simulator with all but the center channel turned off to understand the difficulties of the status quo (i.e., restricted FOV).

Simulation visuals have progressed to the point where photo-textured images from satellite and aerial intelligence assets can be draped over terrain elevation data to produce visual databases that properly depict terrain features, roads, and cultural features sufficient for navigation and Situational Awareness.

Examine the actual screen shot of a PC-based photo-realistic visual of the Nellis USAF Airbase region. (See Figure 1) These higher fidelity visual databases are combined with UAV/UCAV ownship position and orientation information to control the eye point of the simulated visuals so that they correlate to the real-world visuals from the UAV cameras. The simplest application is to provide a wider FOV by providing multiple monitors for the correlated simulated visuals.
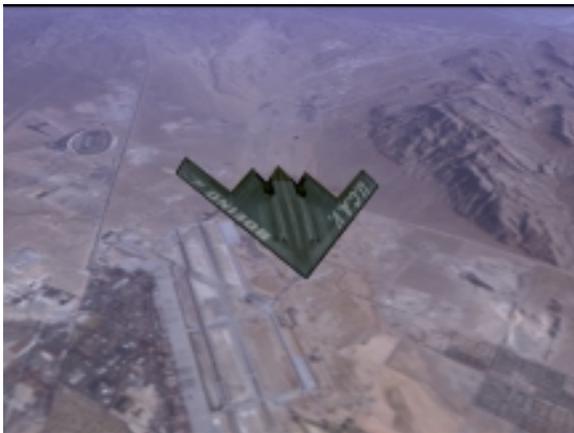

Figure 1
UCAV over Nellis AFB, NV
(Actual Screen Shot, Real-Time 60Hz update,
1024 x768 resolution)

The demonstration UAV/UCAV Synthetic Vision prototype provides additional channels from PCs, with each PC typically configured to support one glass-instruments monitor, and three or four OTW monitors complete with HUD graphics.

The benefits of UAV/UCAV Synthetic Visuals are not limited to augmenting the forward field of view. Synthetic Vision can also augment the camera and sensor operator views enhancing target acquisition and Situational Awareness. To this end, the UAV/UCAV Synthetic Vision prototype also supports alternate use of four OTW monitors serving as an Electro/Optical Pod camera, complete with zoom. The human factors design of an effective set of overlay graphics to aid the operators in orientation during camera or sensor slewing from a moving UAV/UCAV platform remains to be done. However, the UAV/UCAV Synthetic Vision prototype seemed to be easier to use when the horizontal and vertical lines for the center screen were extended through the other monitors.

Further, navigational cues and overlay graphic highlights can be added to the Synthetic Vision terrain as mission aids. Future linking of the UAVs and UCAVs to AWACS and JSTARS would allow near real-time display of enemy targets in the Synthetic Vision terrain at least sufficient for camera or sensor scanning, release of GPS weapons, or pointing information sufficient for weapon's on board sensors to lock on.

UAV/UCAV Synthetic Vision Implementation

UAV/UCAV integration with Synthetic Vision is a straight forward technical integration of existing ground control stations with existing flight simulation. Basically, it is as simple as utilizing the UAV/UCAV position information to drive eye-point position commands to the simulated visuals. Plus, the UAV/UCAV current camera information driving the Synthetic Vision orientation and zoom attributes. If the actual updates from the UAV/UCAV are not frequent enough for smooth visual updates, the simulation standard DIS IEEE 1278 Dead Reckoning Algorithms (DRA) and smoothing algorithms can efficiently supply the needed updates. The production of the correlated visual database can range from polygon "miss the mountain" type DTED only to photo realistic imagery based visual databases from recent intelligence images.

Synthetic Vision Precursor to Simulation Integration into Operational Weapon Systems

The authors suggests that UAV/UCAV Synthetic Vision is the first rise of a Toffler Third Wave paradigm shift. Simulation has progressed to the point where integration into operational systems can become the preferred practice. Currently, most simulations are developed for training and prototyping purposes in parallel with the operational system development (i.e., until relatively recently, training simulations have been a low priority afterthought). Historical economic rational and engineering constraints, that no longer apply, drove the old methods of operational system development. Current efforts to do increased simulation training, Distributed Mission Training,

simulation based acquisition, and embedded and appended training are all signs of a paradigm shift to increasing integration of simulation and operational equipment. The most critical concept this paper expounds is: "Simulation Systems can be and should be integrated into operational equipment." UAV/UCAV Synthetic Visuals can become an illustrative example for the simulation and operational communities to utilize. It becomes a simple step of new thinking in the Toffler tradition to make the "Quantum Leap" that training simulations can become part of the operational systems. We should select simulation platforms that are compatible with operational platforms. That way, the simulation software can become a portion of the operational system and visa versa. For example, consider our previous example of producing the Synthetic Visuals with two PCs. The PCs can actually run a state-of-the-art avionics simulation on the system and link it to the UAV/UCAV. Advanced terrain avoidance and navigational cues found on F-16 systems can be grafted onto a predator UAV. To address practical matters of implementation in our first example, the 2 PCs are actually able to support an additional VGA monitor for instrument displays. (SDS' LiteFlite™ simulation already supports 3 out-the-windows and a fourth monitor of instrumentation display in photo-realistic visuals at 30-60 HZ).

UAV/UCAV Synthetic Vision Demonstrations

A series of experiments are planned in the near future that will utilize the UAV/UCAV Synthetic Vision prototype as the basic research tool. As a precursor to the actual experiments (pending funding), the following prototype demonstrations were performed.

Synthetic Visuals Augmentation to Enhance Control by Increasing Field-Of-View

A simple demonstration of a landing at Nellis AFB was performed in a control condition where monitor #2 was the only channel operating (i.e., status quo, reduced FOV). That was followed by the same landing task with two treatment conditions. Treatment conditions are planned as: 1) Two additional Synthetic Vision Monitors with no fog , no clouds, no haze, daylight, 40 miles visibility; 2) Five additional Synthetic Vision Monitors with no fog , no clouds, no haze, daylight, 40 miles visibility. Actual experimental measurements will be performed when the research efforts are funded. However, it only takes a few minutes of flying the Synthetic Vision treatment conditions to ascertain for oneself that using the larger FOV seems to be easier. The planned experiments will attempt to verify this observation by performance scores and NASA TLX post-test surveys.

Synthetic Visuals Augmentation to Enhance Control in Poor Weather / Lighting Conditions

Poor conditions, including night-time conditions and simulated fog / clouds, were demonstrated and initially investigated by fogging and reducing the time of day attribute of the center channel. The initial observations from the demonstration can be characterized as SV is superior to instrument flying only. The use of ground features for guidance is more intuitive for basic simulated UAV or UCAV control. Eventually the Synthetic Visuals will be utilized in a demonstration of enhanced Situational Awareness in poor visual conditions by either actual flight of a UAV (or a RC plane with video) during poor visibility conditions including night-time conditions and simulated fog / clouds via smoke bombs. Again, future experiments are planned to verify these observations.

Synthetic Visuals Augmentation to Enhance Terrain Avoidance and Navigational Cues.

The simulated UAV/UCAV predator prototype was demonstrated with reconfigured software that mimicked portions of the F-16 avionics system. The prototype implementation utilized the simulated HUD graphics over all of the Synthetic Vision displays and utilized the VGA card of the PC to display instruments. Terrain Avoidance and Simulated Radar Threat Cues were placed on three screens. Performance scoring and NASA TLX Testing results utilizing experienced UAV pilots or alternately Remote Control flyers are planned.

Synthetic Visuals Augmentation to Near Real-Time Weather Cues.

The UAV/UCAV Synthetic Vision prototype is planned to include near real-time weather information to facilitate controller Situational Awareness. One of the planned uses of the weather information is to aid in judging the actual UAV's position over the target by matching "hole-in-the clouds" as shown on the Synthetic Vision display. Further, it may be possible to utilize that same weather information to aid in visual and partial IR masking of the UAV or UCAV during mission flight. Baron Services Doppler Radar software will be initially utilized to supply the weather images to the SV displays.

Synthetic Visuals Augmentation to Enhance Video scanned Area Cues.

This portion of the UAV/UCAV Synthetic Visuals prototype has not been developed yet. The effort will require sophisticated real-time modification of terrain skin mesh to properly support highlighting scanned

surfaces partially occulted by hills and other features. A simpler version would utilize the material codes of each terrain polygon to modify the lighting function for each polygon "scanned" by a ray-trace or intersection detection from the camera position. In Predator UAV missions, one of the difficulties facing controllers is keeping track of actual area coverage verses assigned areas. Here again, use of Synthetic Visions applications should significantly aid controller Situational Awareness. Specifically, the planned demonstration will illustrate the use of highlighting every pixel on the simulated views that the real-world camera has seen. This highlighted terrain can be rotated and viewed form above to show hidden valleys and low areas that might otherwise be missed, thus significantly increasing Predator sortie effectiveness by identifying areas for re-attack in real-time.

Discussion – Synthetic Vision Precursor to Simulation Integration into Operational Systems

UCAV integration with Distributed Interactive Simulation (DIS) is an innovative low risk area of research that has the potential to rapidly develop UCAV products. Existing DIS Simulators are designed to effectively apply Man-In-The-Loop Control in a limited communication bandwidth environment. Further, existing DIS Synthetic Forces such as AirSF apply advanced artificial intelligence resources to respond with appropriate behaviors in complex battle spaces. A UCAV controller can maintain effective Situational Awareness by flying the UCAV in a DIS simulator with a geo-specific terrain, fully populated with friends and foes as detected by theater and tactical sensors. The DIS simulator provides the Man-In-The-Loop controller the required context, visual cues and sensor information without constant video or sensor data transmission from the UCAV. A key concept of this paper is the realization that a DIS simulation of a UCAV in combat can actually control the operational UCAV. The idea of using simulator software in actual operational equipment is relatively new, but is the logical conclusion of the blurring distinction between simulators and their associated operational equipment. Originally, simulators were designed simply to emulate actual operational equipment. However, over time, simulation has evolved to the point where it actually uses operational equipment software as illustrated by USAF efforts such as Armstrong Labs utilization of F-16 operational flight software in their MTT F-16 simulators and the US Navy Aegis programs similar integration of operational and training software. The original relationship of operational equipment as the data source with the simulator emulation as the data receiver has evolved to equivalence in the case of software duplications between simulators and operational equipment. The reversal of information flow from the simulator to the operational equipment can be considered as a precursor to this proposed effort. The various Battle Labs prototyping weapon system development via simulation (BLRSI) and USAF design, development and actual implementation of actual flight instruments from VAPS are examples of design information flowing from simulation to operational equipment. This paper advocates the next logical development, that is, the control of the operational UCAVs from DIS Simulator Interfaces. Further, the reuse of existing DIS/HLA products that support Man-In-The-Loop Controllers with intelligent Synthetic Forces behaviors can greatly benefit the UCAV program. Specifically, DIS simulator control of UCAVs can increase their performance, reduce the development risk, reduce the development time, and reduce the associated initial and life-cycle costs.

The DIS architecture can reduce the transmission of information requirements between the controller and UCAV in the same manner as DIS reduced transmission of information requirements between simulated entities. Additionally, the integration of DIS tends to limit the UCAV as an emitter of radiation and, therefore, reduces its probability of detection and the utilization of the UCAV emitted radiation by threats to target it. The UCAV computers utilization of DIS Dead Reckoning Algorithms (DRA) in parallel with the Controller Computers reduces communication requirements. Specifically, the frequency of communication is reduced by the DIS bounding box structure where each network node (UCAVs and Controllers) only transmits a network packet (DIS PDU) when an entities actual position is greater than the Dead Reckoning Thresholds. In addition to the obvious advantages of reduced transmission of ownship data, the application of DRA to UCAV passively detected targets reduces the updates required--updates to the controller would only occur when targets actual locations varied outside the DR Thresholds. For example, consider the case of a UCAV intercept of 2 MIGS. The initial intercept vector and instructions are transmitted from the AWACS controller to a stealthy UCAV with two IR passive sidewinders. The UCAV follows the assigned vector navigating with GPS or internal gyro. Corrections would be sent as the bandits maneuver until one of the UCAV's sidewinders locked on to a bandit. A weapons release request would be sent from the UCAV to the controller who would still fire the weapon. In extreme EW conditions, the UCAV may have its own IFF system and launch weapons based upon its rules of engagement encoded in the AirSF behaviors. Research should be aimed at developing flexible solutions with multiple alternatives from tightly controlled to entirely autonomous self-control by the UCAV ownship computers. The mission

space may require a mix of control alternatives to be applied throughout the phases of the mission. For example, using the DIS Aggregate functions, a number of UCAVS are flown to a marshaling point by a single controller. The DIS De-Aggregate and SIMAN functions are then used to parse-out assignments of individual UCAVs to AWACS controllers. The AWACS controllers would set the behaviors, way-points and mission orders to their UCAV. They would also send Secondary Behaviors and Mission Orders in case of communication loss. If the EW environment permits it, the UCAVs can transmit information to the controller for frequent positive control. However, if the EW environment does not permit UCAV transmission but the AWAC's signal strength can still be received by the UCAV, positive control by the operator can be maintained. If complete communication loss is anticipated, target data should be sent to the UCAV as long as possible so that the AirSF behaviors can attempt to acquire and destroy the enemy threat based upon its last known location, state information, and taking into account enemy tactics. Finally, if no communication is anticipated, the UCAV can fly to the target area and, in the case of ground targets, deliver GPS bombs or actively search for and destroy recognized targets. Early UCAV prototypes can be utilized as smart bomb ferries where the UCAV merely fly to a predefined location, speed and altitude to ensure the GPS bombs have enough momentum and altitude to fly to their prescribed targets.

SYNTHETIC VISION PRECURSOR: LITEFLITE PC-IG VISUAL SYSTEM DEMONSTRATION

One additional visual system demonstration has great significance for the future of PC based Synthetic Vision Systems. Specifically, a Historic PC-IG Milestone has been marked. The authors, working cooperatively with Quantum3D and the Air Force Research Laboratory Warfighter Training Research Division (AFRL/HEA) have successfully driven one of the Air Force's most advanced visual display systems, the Mobile Modular Display for Advanced Research and Training (M2DART) with SDS International's PC-based, LiteFlite[TM] DIS Stealth Visual System using Quantum3D's Heavy Metal Max hardware and a high-fidelity, photo-realistic visual database developed with TerreX and 3D models with View Point Labs.
For this demonstration, the team replaced the Lab's existing non-PC-based Image Generators (IG) and associated visual databases with its PC-based system, while maintaining the integrity of the M2DART. The demonstration proved that today's PC technology, when coupled with an innovative software integration approach, can drive current out-the-window visual displays with synchronized, multi-screen photo-realistic imagery running at 60hz.
At $1/20^{th}$ to $1/30^{th}$ the cost of higher-end, non-PC-based IGs, the implications for legacy and emerging flight simulators are impressive—the resultant dramatically improved price performance ratio for military visual systems can make high fidelity, photo-realistic visuals capable of operating in a DIS environment an affordable reality.

The importance of acceptance of PC-IGs as viable low-cost solutions has immediate benefits for Synthetic Vision Systems. Consider an M2DART like 360 degree view environment for the 911 crisis manager to utilize in helping pilots needing assistance. Beyond 911 applications imagine the potential benefits of having such mirror sites that allow command, and control personnel to monitor missions from the perspective of the pilot.

OBSERVATIONS & CONCLUSIONS

Synthetic Vision displays appear to have benefits, advantages and sufficient merit to warrant further investigation and support for the technology. Synthetic Vision research and development should be an integrated effort between the research, simulation and operational communities with a robust mix of human factors, subject matter experts, operational and simulation/training personnel. The authors urge the communities to adopt the draft Synthetic Vision framework proposed in this paper, to modify and adopt the framework, or to develop a new framework to allow our formerly disparate communities to communicate in a standard language.

Synthetic Vision applications are not limited to providing information to human pilots. The ownship information and terrain data can be utilized by artificial intelligence to control the aircraft. For example a Synthetic Terrain Following Application could provide the same functionality as a Terrain Following Radar system without the combat risk of an emitting radar.

The concept of using the case based terrain reasoning of ModSAF or AirSF to automate control of UAVs and UCAVs may have benefits in reducing manning levels required for control. This concept also illustrates the develop once (for the simulation community) and use twice (for the simulations and operational systems)

Adopting Synthetic Vision system standards will aid development of planned air traffic control systems and accelerate the fielding of systems and associated services.

Enabling technologies are on the horizon, High Bandwidth Low Earth Orbiting (LEO) satellites and 10 pico-second pulse technology from TimeDomain will support a entirely new generation of Synthetic Vision Displays. We urge the simulation and operational communities to work together to apply these new enabling technologies to Synthetic Vision and related systems for the benefit of all.

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