VISUALIZATION SOLUTIONS FOR AVCATT-A RECONFIGURABLE COCKPITS

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ABSTRACT

The Aviation Combined Arms Tactical Trainer – Aviation Reconfigurable Manned Simulator (AVCATT-A) is the Army's newest aviation training simulator. It is a dynamic reconfigurable system used for combined arms collective training and mission rehearsal through networked simulators in a simulated battlefield environment. AVCATT-A will provide training for both active U.S. Army and National Guard units. AVCATT-A provides five functional cockpits. These are the OH-58D Kiowa Warrior, the AH-64A Apache, the AH-64D Longbow Apache, the CH-47D Chinook, and the UH-60A/L Blackhawk helicopters. To meet the visual needs of all these cockpits, AVCATT-A is employing state-of-the-art technology. This includes the Image Generator, the Helmet Mounted Display, the Multifunction Displays, the Secondary Displays, Head Trackers, and reuse of the Close Combat Tactical Trainer (CCTT) terrain databases. This paper will describe the AVCATT-A visual system and the challenges encountered in meeting the requirements for each cockpit.

ABOUT THE AUTHORS

Rita Simons is currently a Visual Systems Engineer at STRICOM, responsible for the visual system requirements on the Aviation Combined Arms Tactical Trainer – Aviation (AVCATT-A) reconfigurable manned simulator. She is also the COR on three visual technology based SBIRs. She earned a Bachelor of Science degree in Electrical Engineering from the University of Central Florida (UCF) in Orlando, FL and is currently pursuing a Master of Science degree in Simulation at UCF.

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Jim Melzer is a Product Manager for Head-mounted and Miniature Displays at Kaiser Electro-Optics, in Carlsbad, California. He has been designing and building HMDs for over 17 years for a variety of applications including medical, professional, training and simulation, fixed-wing and rotary-wing, and dismounted infantry. He holds four patents in HMD design and has authored over 25 technical papers including a co-edited book: *Head-Mounted Displays: Designing for the User*, published by McGraw-Hill.

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INTRODUCTION

The U.S. Army STRICOM's Aviation Combined Arms Tactical Trainer-Aviation (AVCATT-A) is the Army's newest aviation training simulator. It is being developed as an aviation collective training virtual simulation system specifically designed to help commanders achieve and sustain unit proficiency and combat readiness. Current Army aviation simulators are stand-alone simulators for specific aviation aircraft, such as the Apache Combat Mission Simulator (CMS), or the Lift Simulator Modernization Program (LSMP) which is an upgrade of the existing Blackhawk and Chinook flight simulators. These simulators are full motion, high fidelity flight simulators designed to teach the aviator how to fly these specific aircraft. They are not used as collective trainers and are typically not networked together. AVCATT-A fulfills this requirement for Army aviation. It will provide a unique capability to allow units to train as units, and not as individual aircrews. AVCATT-A is required to provide the capability to conduct realistic, high intensity, task loaded collective and combined arms training exercises and mission rehearsals. It must be capable of simulating current Army attack, reconnaissance, cargo, and utility aircraft.

BACKGROUND

The full motion, aircraft specific flight simulators are invaluable in teaching basic flight skills, and aircraft operation. Once those skills have been mastered, the next step is learning how to operate as a unit. The full motion flight simulators are very expensive to procure, and also to maintain. They are typically fielded with only one simulator per site, are not fielded in abundance, and are scattered throughout the world. To network the simulators together for collective training would require costly long haul networking, which is difficult in itself, along with the requirement to long-haul to different parts of the world. In addition, at the end of the training exercise, the value added for unit training is the ability to After Action Review (AAR) the exercise. If your aircrews are geographically separated, conduction of the AAR also becomes difficult and costly.

To fill this void, the concept of AVCATT-A was developed to be able to provide collective/combined arms training. This provides the ability to teach Army aviation pilots to function as a unit. It is assumed that pilots using AVCATT-A will have already been through flight training, therefore cockpits may have selective fidelity. The simulators in AVCATT-A are required to perform like specific aircraft, but not necessarily have the exact replication of every switch, knob, or system necessary for teaching basic flight skills. With this idea in mind, the next step is how to maximize the number of aircraft that can be utilized to cover the number of aircraft requiring collective training. The answer to this was to make the simulators reconfigurable.

The requirement for AVCATT-A is to provide as many different aircraft configurations as available for training. In order to meet this requirement, AVCATT-A is required to support unit collective training utilizing reconfigurable simulators. Reconfigurable simulators are different aircraft configurations that can be adapted for training, sharing the same basic platform. This allows leveraging of common components, and provides a capability to train on one specific aircraft, or to train with multiple different aircraft.

WHAT IS AVCATT-A?

AVCATT-A is a mobile, transportable, virtual simulation training system. The physical layout of an AVCATT-A suite consists of two trailers connected by a raised, covered platform. One trailer includes three reconfigurable manned modules and a 20-person After Action Review (AAR) facility. The second trailer includes three reconfigurable manned modules, a Battlemaster Control room, and a maintenance room. AVCATT-A provides a total capability of six manned module cockpits per suite, networked together to help train an aviation company or air cavalry troop (see Figure 1). Each manned module has a requirement to be reconfigurable to current Army attack, reconnaissance, cargo, and utility aircraft. AVCATT-A has the capability to be linked via local area network (LAN) and/or wide area network (WAN) with other AVCATT-A suites, and other combined arms tactical trainers such as the Close Combat Tactical Trainer (CCTT). It will also have the capability to be linked to other Distributed Interactive Simulation (DIS)/High Level Architecture (HLA) compliant systems, and multiple digital and/or nondigital Tactical Operations Centers (TOC). This provides the capability to conduct collective training from team through combined arms levels.

Figure 1 AVCATT-A Suite Layout

AVCATT-A Reconfigurable Cockpits

The first cockpits being developed for AVCATT are the AH-64A Apache, AH-64D Apache Longbow, OH-58D Kiowa Warrior, UH-60A/L Blackhawk, and CH-47D Chinook. The RAH-66 Comanche will also be provided and is currently undergoing requirement definition. In addition to satisfying the requirement to be reconfigurable, AVCATT-A must also be capable of reconfiguring the manned modules and initializing with pre-built scenarios within a 90 minute time period. Another requirement that affects AVCATT-A is that all the parts required for the various configurations must be contained within the trailers. This eliminated the potential for roll-in/roll-out cockpits.

The basic design issue for AVCATT-A was to accommodate all of the aircraft configurations with a single generic hardware solution and as much common software as possible. The computers, image generators, visual displays and the software that drives them must be common to all of the configurations. For the hardware solution, the supporting structure, control loaders, anti-torque pedals, and seats must be common to all of the configurations.

AVCATT-A VISUAL APPROACH

The cockpit for each of the above mentioned aircraft are different. The Kiowa Warrior, Blackhawk, and Chinook require that the seats be side by side whereas the Apache requires that the seats be tandem. The ability to reconfigure from side by side to tandem cockpits had to also be addressed. Rather than trying to move the seats, the approach was made to change a side by side cockpit to a tandem configuration by changing the visual perception of the crew. This was accomplished by using individual cockpit masks through the visual display system.

Each aircraft has a unique cockpit mask, unique eye points, and different flight instruments and controls. The requirement for the visual system is to accommodate the cockpit requirements for each aircraft, provide the correct visual perception for each aircraft, and maintain a positive training environment for the different aircraft types.

Cockpit Masking

The cockpit mask is a visual representation of the cockpit that is anchored within the visual scene displayed. The mask is dynamic in that it is redrawn in response to head movement so that you can see around cockpit obstructions by moving your head. If there is no obstruction between a crewmember's Line of Sight (LOS) and the window or windscreen, then an out-the-window (OTW) scene is drawn. If there is something in the LOS, then the obstruction is represented in the visual scene with transparent black polygons. For example, when the crewmember looks down at the instrument panel, the mask interrupts the OTW scene at the correct point and allows direct viewing of the instrument panel. In a side by side configuration, the mask allows the crewmembers to look across the cockpit and see things as they normally are. In a tandem configuration, the masking is changed to portray the support structure of the canopy and a black fabric curtain is placed between the seats to prevent illumination from the other cockpit to bleed through the visual scene. Although the crewmembers are physically sitting side by side, their visual perception has been changed. If they look towards each other, they will only see the OTW view associated with their particular seat in the cockpit.

Crewmember Design Eye Points

The design eye point is where a graphical perspective is optimized for the aircraft, for the crewmember's viewpoint. The design eye point is the seat position aircraft engineers have planned for best visibility for a given aircraft, and is a reference point from which all points in a cockpit are measured. Similar to placement of a car seat, if the design eye point is too high, then the crewmember feels that he sits too high in the aircraft. If the design eye point is too low, he feels that he sits too low. If it is too far forward or back, then he feels like the cockpit instruments are either too far forward or too close. To design the eye points for each cockpit configuration, AVCATT-A relied on existing aitoff plots for the AH-64, CH-47, and UH-60. Unfortunately, aitoff plots for the OH-58 were not available, forcing AVCATT-A to rely on pilot input as to the location of the design eye point. Aitoff plots will also be utilized for the RAH-66. The design eye point was used to establish correct cockpit masking, and to ensure that the visual scene displayed is correct. If a pilot expects to be able to see through a chin window, by glancing down to his left, then the window (or at least the visual perception of a window) needs to be there. The other problem was placement of the cockpit instrument panels for each aircraft (see Figure 2). With a common hardware platform, it is challenging to get the placement of each instrument panel into the correct positions for the crewmembers. To find the optimal position for the instrument panels, a common eye point was determined by considering the worst case laterally, longitudinally, and vertically. The widest cockpit is the UH-60, which was used for the worst case laterally. To determine the longitudinal and vertical positions, all of the aircraft design system points were plotted. Once these were plotted, a compromise eyepoint for the pilot and cockpit were selected. The instrument panels were then placed into the cockpits, and were adjusted horizontally so that the side look angles from the eye point were correct, and vertically so that the down look angles were correct.

Figure 2 AVCATT-A Reconfigurable Cockpit

AVCATT-A VISUAL SYSTEM CONFIGURATION

The AVCATT-A visual system creates the OTW and sensor imagery view. The major components of the AVCATT-A visual system are the Image Generator (IG), two Helmet Mounted Displays (HMD), two Multifunction Displays (MFD), and two secondary (backup) displays (see Figure 3).

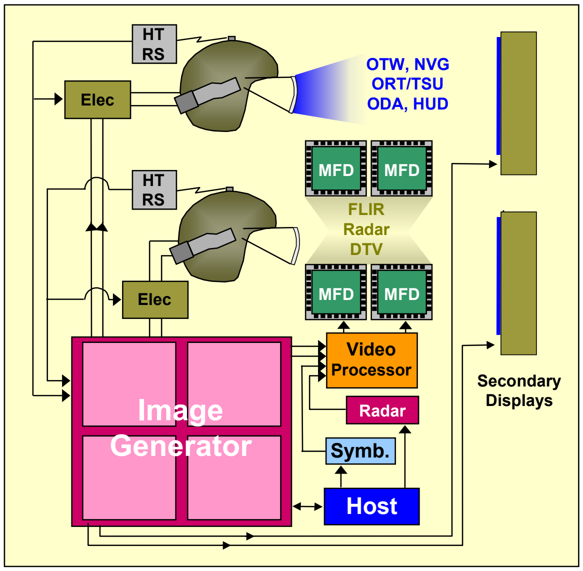

Figure 3 AVCATT-A Visual System Configuration

The AVCATT-A crewmembers have the capability to view a 360° field of regard virtual world that is unique per simulated rotor configuration. Visual scene cut outs for windows, chin windows, and instrument panels are all defined for each specific aircraft configurations. The IG provides the imagery for the pilot and copilot, as well as two sensor channels. The image generator, headtracker, and HMD electronics are tightly coupled in order to present a responsive, and stable image to the pilots. The HMD utilized for AVCATT-A provides a total Field Of View (FOV) of 100 degrees horizontally by 50 degrees vertically. The FOV for each eye is 65 degrees horizontally by 50 degrees vertically with a 30 degree overlap region which enhances the 3-D visualization experience of close in objects (such as looking around the window struts, and parallax effects). During night operations, night vision goggles are simulated in the HMD. Single panel 41 inch plasma panels are mounted directly in front of each crewmember and are only utilized if the HMD fails. During normal operations, they are covered up with black fabric in order to minimize reflection, and cover up the display lights (such as the ON/OFF button) which can distract the pilot. The secondary displays show the same imagery and pilot symbology as are shown in the HMD but are limited to the forward view only.

The MFDs portray sensor imagery for each crew member. Either Forward Looking Infrared Radar (FLIR), Day TV (DTV), or both can be selected depending on the aircraft configuration. Symbology is embedded in the sensor video with the capability to add additional symbology and video reformatting by the video processor to support unique sensor video to multiple stations. The sensor functionality is tailored for each support aircraft configuration.

These major components, when integrated together, provide the capability to conduct collective training from team through combined arms level. Many technical challenges were encountered during development of the visual system requiring innovative solutions to fully support the training need.

Image Generation

The six channel IG provides the pilot left and right eye, copilot left and right eye, and two sensor channels of imagery. The secondary displays render the right eye viewport of the pilot and copilot channels when the HMD is not in use. The key challenge of the image generator was to maintain a 60Hz update rate and minimize transport delay in order to minimize simulator anomalies in the HMD. The IG is required to process the terrain database as well as handle the large quantities of moving models. An entire AVCATT exercise can handle 10,000 entities, however only 128 are required to be rendered in the visual scene. To accomplish this, multiple filters based on priority are used to select the moving models until only the final displayable entities are rendered. The responsibility of the IG runtime software is to monitor system performance implementing overload management as required. Ownship location and the HMD look angle which is based on tracker prediction are also combined in the IG runtime software to ensure a responsive head tracking system. In addition, the IG is also responsible for updating time of day, sensor effects, and image illumination source information.

The IG runtime software in AVCATT-A is responsible for the mission functions, database functions, cull functions, and draw functions (see Figure 4). Mission functions include collision detection (body strikes, rotor strikes), Height Above Terrain (HAT), Line Of Sight (LOS), terrain clamping, laser range finding, and head tracker output data. LOS information, HAT, and collision detection are derived from the common databases derived from Synthetic Environment Data Representation and Interchange Specification (SEDRIS) Transmittal Format (STF). The mission function architecture is modular and expands as the complexity of the battle increases the demand for more data requests. The database function supports the Digital Terrain Elevation Data (DTED) terrain derived from SEDRIS. Cultural feature models and moving models have multiple levels of detail and several states. Each model has a normal, damaged, and destroyed version. Relocatable models are positioned at mission start, moving models are assigned to the database and are prioritized for overload culling. Special effects enhance the simulation providing dust trails, rotor wash, and weapons effects. The cull functions determine the field of view content. In this function, LOD is selected for the terrain and models, incremental animation effects are updated for display, and channel specific polygons are selected for Infrared (IR) and Night Vision Goggles (NVG) effects. The draw function begins the process of converting database coordinates to display coordinates. Per pixel content is determined by color (material code driven), shading, artificial illumination, time of day, night illumination, and weather. Symbology is then overlaid on the video as required.

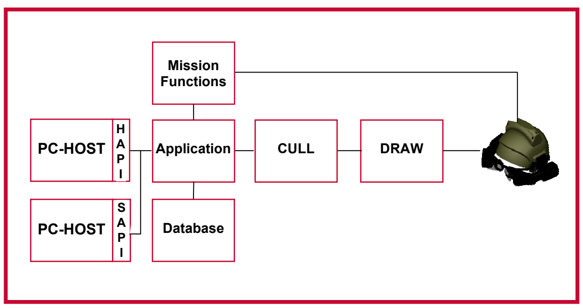

Figure 4 IG System Block Diagram

Display system

Aviators have been the most demanding display user, requiring a 360 degree FOV to enable them to perform aircraft maneuvers. They depend highly on their peripheral vision that cannot be provided by flat panel displays. One other display alternative is to use domes. Domes can provide the FOV required but are expensive to maintain and require a large area to house them. With the requirement to be housed in a trailer, domes were out of the question. To meet the aviator's needs for FOV, the only alternative to installing a space demanding and expensive dome, was to use a HMD. Recent developments in computer image generator technology, head tracking, and in particular image source technology has allowed the use of HMDs as the primary visual display system. HMDs are an effective means for aircraft simulation and training that is both low cost and portable.

The primary visual display system in AVCATT-A is the HMD. AVCATT-A is utilizing the Kaiser SIM-EYE XL100A. The AVCATT-A HMD.provides a 50° vertical by 100° horizontal field of view (see Figure 5). As mentioned above, cockpit unique masking is utilized in AVCATT-A. When displayed in the HMD, this mask gives the pilot and copilot a visual perspective of the size and shape of their unique cockpit. They can look out the window or can move their head to view an object situated behind a window strut.

Figure 5 AVCATT-A HMD

The SIM EYE XL100A is a high-resolution, full-color head-mounted display that traces its origins to the WIDE EYE helmet-mounted display designed for the US Army LHX program which was the predecessor to Comanche.

The display portion of the HMD consists of two individual monoculars mounted to a rigid central frame. Each provides a 65° horizontal by 50° vertical field of view. Each monocular is canted outward by 17.5° for a total horizontal field of view of 100° with a central 30° partial binocular overlap region (Melzer and Moffitt, 1991). Each image source assembly contains three miniature XGA (1024 x 768) resolution LCD panels each with a monochrome (red, green and blue) backlight. Display luminance is nominally set at 25 fL, though this can be adjusted either higher or lower depending on the simulation requirements.

The pupil forming optics relay the color display to the user presenting a 15 mm exit pupil with 30 mm eye relief via the VIM eyepiece (Berman and Melzer, 1989). See through transmission is a color-neutral 20%. The shape of the eyepiece assembly has been carefully designed to minimize the obscuring structure.

The rigid carbon fiber structure maintains the rigid binocular alignment tolerances required to provide long term viewing comfort (Moffitt, 1997). Precision mechanisms allow the setting of user-specific interpupillary distance in a timely manner. The binocular display assembly attaches to a lightweight "one-size-fits-all" helmet designed specifically for simulation applications. Fitting is done using a combination of nape and crown pads and air bladders.

In order to determine the head location and orientation with sufficient accuracy to make adequate use of the cockpit masking features, a 6 degree-of-freedom (6DOF) head tracker is mounted on the top of the helmet. Orientation angles (α, β and γ) are determined by an inertial sensor and head location (in x, y, and z) is determined by an ultrasonic sensors.

Total head-supported weight (HMD + head tracker) for 6.5 lb in the Lot 1 deliveries. An aggressive weight reduction program on the HMD reduced this to 5.72 lb in the Lot 2 systems. Further weight reduction is possible to approximately 5.1 lb with efforts focused on the lens design and the head tracker. Other potential improvements currently being studied include an increase in display resolution from XGA to SXGA (1280 x 1024), and a reduction in the image latency associated with the response time of the LCD image sources.

Serving as backup displays, the secondary plasma displays are not used if the HMDs are functional. (see Figure 6). Since the secondary displays only show the right eyes of each crewmember, they provide limited training during a tactical engagement when compared to the HMD. Its key benefit is the continued participation of the pilot and copilot in the training exercise.

VISUAL TERRAIN DATABASE

The requirement for AVCATT-A was to utilize existing CCTT terrain databases. The databases were provided in STF which was then used as source data for the AVCATT-A databases. The key technical challenge has been taking the SEDRIS data and populating all the internally required fields to generate the seven databases that AVCATT-A requires. These seven databases support the various subsystems in the AVCATT-A simulator and provide correlation between systems. To accomplish this,

Figure 6 AVCATT-A Secondary Displays

AVCATT-A developed a database tools suite, composed of commercial and custom tool sets that output the required databases (see Figure 7).

To describe the database generation process for AVCATT-A, the CCTT STF is first read into the Internal DataBase (IDB) structure where various commercial and custom tools can manipulate it. This intermediate format allows the best available tools to be used to achieve the desired objective. The tool then manipulates it to be able to utilize it in an aviation environment. For example, aviators are not concerned with bushes and small rocks whereas ground vehicles may be. Examples of manipulation would be improving texture maps, 3D model changes, or terrain optimization. Once the manipulation is completed, the material reference file is checked and updated to ensure the databases are properly encoded for OTW, IR, NVG, radar, and other data formats.

From this common IDB source, the various databases (DTED, Radar, Image Generator (IG), postscript, Compressed Arc Digital Raster Graphics (CADRG), and Compact Terrain Database (CTDB)) are then generated. These databases support correlated OTW, IR, Radar, paper maps, Stealth Viewer, Semi Automated Forces, radios, and mission planning systems. The current AVCATT–A toolset supports the CCTT P2 (National Training Center) and P3 (Fort Hood) terrain databases. Once the CCTT P6 (Combat Maneuver Training Center (CMTC)) database is produced, AVCATT-A will update their toolset to support P6.

In addition to databases, AVCATT-A is also reusing existing moving models. For ground models, AVCATT-A is using CCTT existing models, increasing the damage models. An observation was made by the AVCATT-A user community that the damage needed to be more obvious. Currently in CCTT, when a tank undergoes a firepower kill, the turret will lean to one side. From the air, and at a distance, this damage is not noticeable. For the air models, AVCATT-A is reusing the 8th Army air models. The 8th Army air models are appropriate for the level of fidelity required for AVCATT-A, but they lack FLIR signatures. AVCATT-A is adding the FLIR signatures.

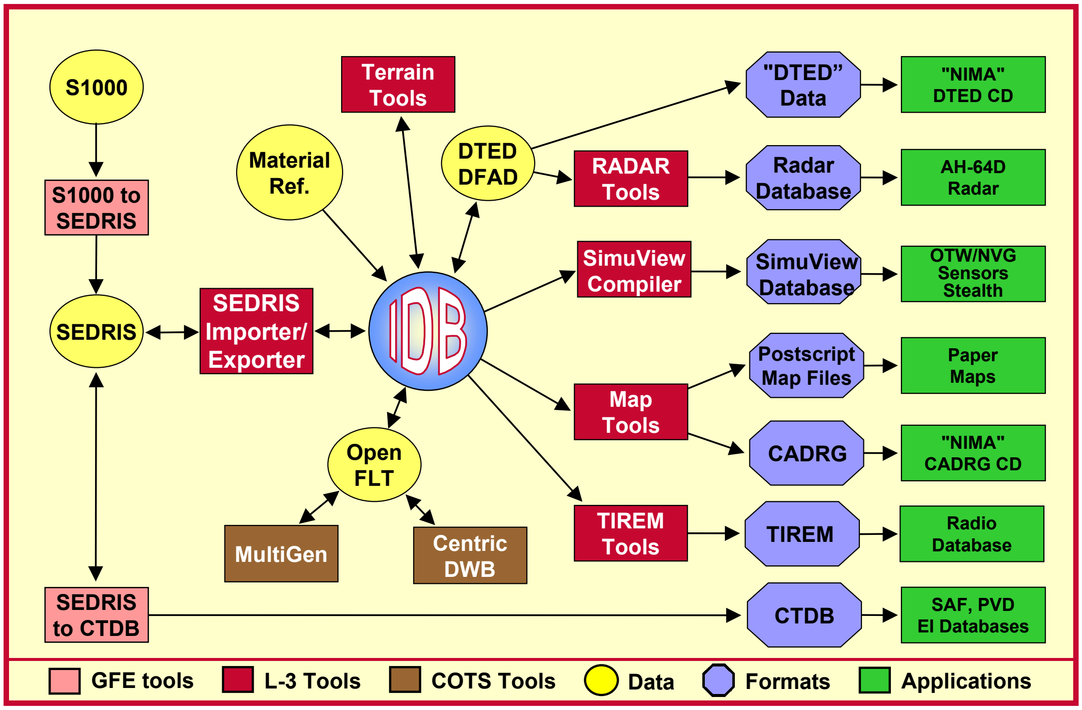

Figure 7 AVCATT-A Database Toolset

CONCLUSION

In today's increasingly sophisticated simulated world, realism is now the expectation of the military user community. The requirement for Army aviation simulators/simulations is to provide a realistic, high intensity, task-loaded environment to effectively train aviation aircrews. Army aviators require training that supports nap-of-the-earth (NOE) flying as well as the ability to conduct multi-ship operations. The performance of the visual system must satisfy the expectation for realism. With the additional requirement to be reconfigurable between multiple platforms, and for mobility, AVCATT-A faced many challenges to meet the requirements. Our innovative HMD solution provides an emersive visualization for collective training. The visual system that will be fielded with AVCATT-A meets the challenges, and leads the simulation world for Army aviation.

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