



3D CAD Finite Element Analysis can spot stresses and potential weak points in the simulator structure.

Image credit: Opinicus Corporation.

The CG Factors

Two CGs – Center-of-Gravity motion forces and Computer-Generated visual and sensor imagery – are both critical to delivering realistic cues to pilots, ship commanders, and ground vehicle drivers. Rick Adams looks at a few recent developments that are enhancing training capabilities.

If you're going to throw some weight around, especially the 30-40,000 pounds of an aircraft weapon systems trainer, you need a pretty precise understanding of how that mass in motion moves around the six degree of freedom envelope.

"The key isn't just the weight. It's more the center of gravity," says Jim Takats, president of Opinicus. "You need to understand the inertia and the forces out at the extremes, such as a rejected takeoff scenario."

Opinicus, which prides itself as "an engineering company which does manufacturing," cut its teeth on motion control and control loading systems, represented today by their RealCue and RealFeel products. But they've quietly developed a reputation for performing major surgery on service-life extension platforms.

The Lutz, Florida-based firm is currently handling major WST motion and other upgrades on behalf of Lockheed

Martin for a very demanding customer, the US Air Force Special Operations Forces. AFSOC's two C-130H simulators, an AC-130U Gunship WST, and a MC-130P are all evolving to what Takats calls a "Level D-plus" standard, and will be evaluated on a recurring basis by government "SIMCert" specialists, primarily ex-FAA simulator inspectors.

Some simulator upgrades, whether military or civil, are motion-focused: replacing an analog cabinet and circuit boards with a new digital system, which runs from a touch-screen PC and can provide data recording, weight-and-balance testing, smoothness testing ... "and you don't have to drag around strip chart recorders and plug-in leads."

But more common, as is the case with the AFSOC MC-130P for Kirtland AFB, New Mexico, a motion upgrade is coupled with a new visual system. The Kirtland program includes changes to the cockpit, instructor station, aural cue

system, motion system and control loading system, a FlightSafety International Vital 10 image generator and Rockwell Collins/SEOS LCoS projectors.

A switch from CRTs to much lighter liquid crystal on silicon (LCoS) or digital light processor (DLP) projectors can represent a significant weight difference – lowering the simulator's center of gravity, moving the CG forward or backward, and changing "the inertia of the moving mass," according to Takats.

Opinicus conducts various analyses – structural, weight, finite element – and creates a 3D CAD model of the simulator structures to determine what will happen when the weights change. "We don't believe 'when in doubt, make it stout,'" Takats notes. "We believe in using design tools which are very accurate if you know how to use them."

One thing they particularly look for are stresses and potential weak points as the simulator shifts and strains. After analyzing one device, they found a minor crack in the sim frame within inches of where the test identified the highest stress point. "Nothing serious, still within safety margins," Takats commented. "But it validated our analysis."

The motion system may also need to be tweaked to suit special training parameters. For example, a flat buffet effect may be too violent if the simulator weight has been radically reduced.

Losing Weight

WSTs can literally drop upwards of a ton or more when changing to lightweight projectors. Each calligraphic CRT projector in a 5-channel system can weigh 500 pounds or more, or 2500 total. The LCoS projectors only tip the scales around 50 pounds each for proprietary systems with night vision goggle (NVG) capability or as little as 14 pounds per lamp for commercial off the shelf Sony or JVC models. Modifying the projector platform atop the simulator cab may shed more weight. "CRTs require a fairly rigid structure to support their heavy weights. We'll actually remove a lot of this extra super-structure," Takats explains.

However, on some programs, there may also be weight gains. (Sounds like some fad diets.) An old 3-channel visual system may be replaced with a 5-channel system and an 11-foot radius wide-screen display with greater horizontal and vertical fields of view to accommodate aerial refueling training or other mission tasks. NVG capability also adds projector heft.

The overall weight of a typical WST is in the 25-35,000 pound range, and the most common upgrade recently has been replacing hydraulic fluid motion systems with electric motion. Electric systems from the two dominant suppliers to the training community, Moog FCS and Bosch Rexroth, can accommodate up to 28-32,000 pounds (12,700-14,500 kilograms). Some military simulators can approach 40,000 pounds, though, so remain on more robust hydraulic actuators. "Otherwise you'd have to do an overall weight reduction program," which Takats says represents major modifications to the trainer.

Industrial Smoke and Mirrors, Orlando, produces an integrated upper platform and aft cabin (including instructor seats and electronics cabinets) with

an overall weight of 12,500 kg, including half of that for the projector system. Fabricated from aluminum honeycomb panels with bonded aluminum sheets, ISM president Andrew Garvis says the aft cabin is capable of supporting the projector platform "with no other required support structure."

You'll hear terms like "payload" and "gross moving load" from motion specialists, but these aren't well defined. "I prefer to use 'load above the knuckle,'" says Takats. "That isolates the weight of the simulator from the motion hardware." Some vendors, he indicates, use very heavy knuckles – the part where the motion actuators attach to the sim structure – whereas others use very light knuckles, "so it's not apples to apples."

Below the upper "knuckle" assembly, there are also weight and inertia elements to consider. Hydraulic actuators have fluid, which must be pushed by the motion system. And electric systems spin a motor, which creates considerable inertia. The latter can represent a possible safety issue when a problem is detected such as too-rapid acceleration: "The electric motor is spinning so fast, you have to take away the mechanical

energy. With a hydraulic system it's easy to dump the pressure."

Synchronized Latency

The process for upgrading a motion platform is pretty straightforward. Remove the hydraulic legs, position the simulator on aircraft jacks (at the same height as before, so it could be used as a fixed base trainer during the interim), and refurbish the hydraulics. New legs, new motion control cabinet, effectively a new motion system.

But it's often more cost effective to combine upgrades. During the motion system downtime, the projector 'turret' assembly can be changed, including mounting structure and light-tight enclosures. The projector frame may need to be adjusted if the lenses are a slightly different shape from the old hardware. "A lot of times a new image generator is driving the downtime, including the interfaces to the new LCoS projectors."

Takats says the preference for motion testing is "to do it last, when everything is on the system," including the new visual and any aerodynamic model updates. "You want the final weight of the system."

At that stage, engineers are carefully



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monitoring the critical latencies of the motion and visual systems. A significant difference between the two will not only cause negative training, the disconnect could induce pilot sickness.

Latencies, or more specifically, throughput delay – the time between a pilot's control input and when it's felt in the simulator movement or viewed on the out-the-window or sensor scene – were upwards of 150-250 milliseconds prior to the Air Force C-130 upgrades. Some studies show a simulation throughput delay of 150 msec is acceptable; other research recommends 100. Takats indicates they'd like to optimize those down to about 50-70 milliseconds. "The customer has seen tremendous improvement in the product. It's very subtle, but the general reaction is that the sim feels better."

Latency takes three separate paths – motion system, visual system, and instrument panel simulation or stimulation. When the pilot moves the yoke or stick, as the case may be, the signal is sent to the simulator's aerodynamic model for position, velocity, and acceleration changes. Every subsystem the signal passes through for processing adds to the latency. But the motion/visual synchronization gets the most attention.

"The motion system is pretty fast, very high frequency, about 5 to 10 milliseconds" (less than a single frame in a 60 Hz visual refresh), Takats says. "The visual is always the long pole in the tent," The control inputs must be routed through the IG and its graphics processors, where one of the tradeoffs is how much content the user wants to see in the scene. "Do you want to see blades of grass moving in the wash from propellers? A lot of building detail? It takes more processing power. Add scene content, increase latency."

From the IG, the signal travels through the projector. "We can't control the latency in the projector. It depends on what you buy," Takats says says some commercial projectors can be around 40-50 msec, while some that are tailored for simulation or other custom solutions offer as low as 4-8 msec.

The visual path typically lags 20-30 msec behind the motion path. Human factors specialists suggest a throughput delay difference of 30 msec (about 2 visual frames and a 60 Hz system) is not a problem for pilots. If the visual cannot keep pace, Takats says the latency in the motion system can be increased.



Mountain Village Realism

Low density visual scenes may yield inadequate training environments for some missions, according to MetaVR president Garth Smith. They've recently produced a database of an urban area south of Kabul with about 500 buildings in a 2 square kilometer area so the Iowa Air National Guard can train combined forces involving high-speed aircraft, unmanned aerial vehicles, ground vehicles, and joint terminal attack controllers (JTACs).

"To do really effective training, you have to train together. And when you're trying to cross-reference in urban settings, you have to be very precise."

Smith says some urban databases in use "tend to be simplistic. It's easy to find targets. A lot of databases make the terrain flat because it's easier to simulate. But that's not realistic for close air support." Training warfighters in an environment "that accurately represents mountainous regions with small population centers is critical." MetaVR's Afghan village is set within mountains and complex terrain of varying elevation and cave networks.

The new Afghan database also "matches the actual footprint of specific structures." The urban area is part of geospecific terrain covering 9,600 square kilometers. The terrain is also delivered with correlated semi-automated forces (SAF) databases.

Databases for high-flying fighter aircraft "used to be less dense" because high detail was not required. But now with very high-resolution sensor pods, even fast movers need to be able to see the scene at the building level. "The high flyer needs to see what the ground vehicle driver sees," Smith adds. "They all have to see the same database."

Doing Hard Real Time

The German Air Force plans to use a

MetaVR's Afghan village.

Image credit: MetaVR.

new simulator in development by ESG (Elektroniksystem und Logistik GmbH, Munich) to screen helicopter pilot candidates. The FPS-H (Fliegerpsychologisches System – Hubschrauber) simulator will feature Concurrent's Linux-based ImaGen visual hardware and Diamond Visonics' GenesisIG "scenery on the fly" software. "The Luftwaffe wants to be sure they are getting the right candidates," says Ken Jackson, VP development and special systems for Concurrent.

ImaGen's largest order to date, 32 servers, is from Hyundai Rotem for the K-series Tank Platoon Simulators to be used by the South Korean Army. Hyundai Rotem developed the K1/K1A1 main battle tanks and family of ground combat vehicles. Each tank simulator includes 8 channels running Presagis' Vega Prime visualization software.

Jackson claims ImaGen's strength derives from Concurrent's "hard real time" legacy as a simulator host computer developer. "Our IG is not spending time on operating system latency. In that magic moment when you hit the joystick, you want to see what's happening on the screen. You don't want the OS taking a 'housecleaning' break."

Concurrent also offers tools for fine-tuning IG performance. "We work with Nvidia and ATI to make sure their drivers are working their best on our system with no cross-interrupts to slow things down," Jackson explains. "And we can put trace points on the rendering software to know how much time it's spending." The tools will also highlight page faults, "and we can show the operator how to lock it down in memory so it never happens again." **ms&t**