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SPECIAL REPORT

Military ICs

Smart-munitions testing enters digital age

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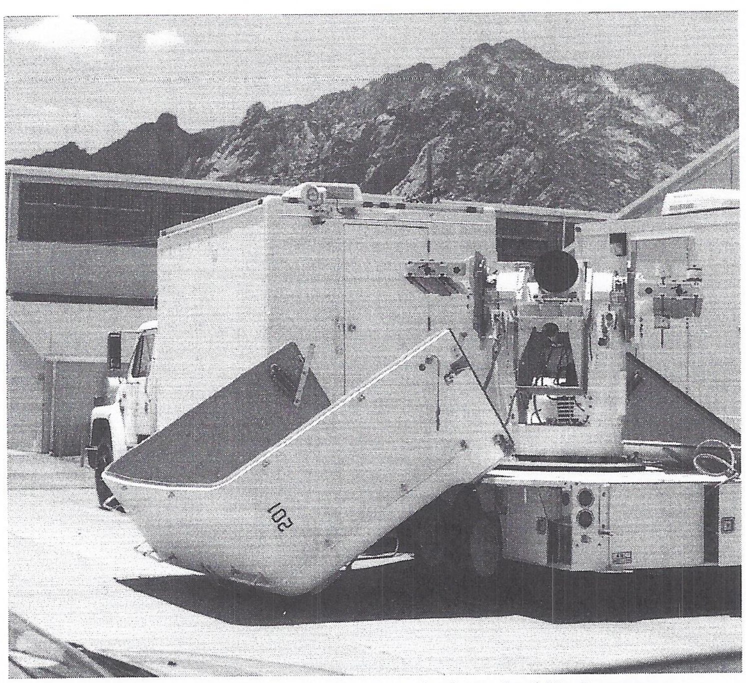
Military test-and-evaluation budgets are shrinking, sending the T&E community scrambling after new technologies that will enable it to survive and fulfill its mission objectives.

In the area of smart and "brilliant" weapon development the effort to optimize field tests while dealing with increasingly sophisticated and complex systems—all under the specter of diminishing funding—is resulting in nothing less than a revolution as all-digital cameras replace film. Pioneering work toward that end is being carried out at the White Sands Missile Range in New Mexico in the Instrumentation Development Directorate by a team comprising engineers and scientists from White Sands, TRW and the David Sarnoff Research Center.

Their work has culminated in the Smart Munitions Test Suite (SMTS), funded by the Defense Department and commissioned about three years ago. The goal was to develop a system to track and record smart-weapons testing while keeping pace with technology gains.

The challenge was to provide and retrieve data for customers on new smart and brilliant submunitions that are jettisoned from various delivery devices. The fundamental problem is that the technology for these weapons was rapidly outpacing the technical instruments used to track and record data on them; moreover, with budget constraints dictating fewer field tests, each must be optimized.

Sarnoff is providing a dual-digital-camera system to capture weapons-test data, an IR camera that is supplemented by a high-speed visible camera. TRW is supplying its TRW Ramcube—a large high-speed memory subsystem designed to capture and store real-time digital data—as well as the interfaces with the cameras.


Mobile van uses infrared camera for black-and-white images.

SMTS was conceived and designed at White Sands to provide a series of endgame truth measurements, where the distinguishing feature of the mission being supported is one of complexity. This may involve tracking as many as 15 or 20 pieces of smart-munitions objects as well as the target ensemble and the carrier platforms themselves.

The number of processes going on completely outstrips the capabilities of the old-style single-point instrumentation systems that the T&E community has typically relied on for the past 20 years or so. Those systems worked well when the object of the mission was tracking high-altitude missiles. As a result, complexity and parallelism of the endgames wasn't a factor.

The specialized SMTS capabilities include a powerful transportable modeling and simulation capability that emphasizes pre-mission planning and rehearsal. This ensures a very diverse set of applications for this innovative system.

Though the typical scenario is ground-to-ground, the SMTS also supports ground-to-air, air-to-ground and air-to-air missions. It can support a wide variety of related missions, where a number of sensors of different types are playing simultaneously.

The SMTS, with modular architecture and sensor-fused strategy, is designed to provide event data and precise time-space position information on this multiplicity of objects as they close, home onto and destroy their targets. The White Sands team feels that this system will, to some degree, replace film as a recording medium.

SMTS will be able to combine elements in a real-time registered (orthorectified) way where the contrast of the IR image is overlaid and corrected for perspective and orientation at real-time rates. The contrast of the IR is superimposed over those details that the visible camera provides and which are to be preserved. The developers have created a kind of image superspace, where they can program the real-time elements they want to capture from the focal planes.

Until a year and a half ago, they could track only one munition at a time. After an explosion, debris would be scattered over a wide area; at that point chances were slim that the human operator would be able to locate and track an object. Moreover, after a "dispense event" occurs, radar is unable to resolve individual munitions for two or three seconds.

Those on the ground have to catalog data and overcome the event as well. The event is so violent that even the IR cameras may suddenly see a big cloud of heat, or the radar may be unable to differentiate between good and bad, and may see one track turn into 20 or 40 because there are no algorithms for their determination. The problem centers on the ability to distinguish between the trash falling, other objects and the carrier itself.

A standard video camera's resolution cannot approach that needed to discern individual pieces, even behind an optical lens. We are especially interested in creating a useful synthetic environment and virtual-to-real entity insertion in a virtual battle space. This would undoubtedly aid smarter testing and, over time, mean fewer tests, reducing the number of errors and bringing down the associated costs.

Contractor data

This new technology will allow White Sands to meet its objective of testing a weapon or system and providing the contractor with all the data for a thorough evaluation, enhancing the accuracy and effectiveness of the programs.

The different types of weapon systems being developed place a heavy burden on the optics platforms to capture visual information of a test when there's a single carrier dispensing multiple munitions. It tends to be very difficult to track objects of interest when there's lots of clutter, pusher plates and other material exploding. This system is basically designed for quick recognition of objects of interest, enabling the team to slave its optics to those desired items.

SMTS has six subsystems:

- Master Control Van (MCV)
- Data-Acquisition and Analysis Van (DAAV)
- Enhanced Multiple-Object Tracking Radar (EMOTR)
- Two Smart-Munitions Distant Object Attitude Measuring Systems;
- Two range-only radars;
- Six Smart-Munitions Tracking Mounts, each with a support van containing a TRW Ramcube, camera interface unit and camera-control equipment.

The MCV serves as the automated mobile command and control center for SMTS. Equipped with a high-speed, global fiber communication system, the van processes and optimally fuses real-time acquisition and tracking data from the collection of sources available to SMTS. The van is configured to directly point up to 12 optical tracking mounts, based on the best real-time solution generated within the MCV TSPI data engine. The TSPI engine serves as a programmable, real-time data fuser generating optical pointing vectors from statistically independent tracking sources.

The MCV also houses the SMTS Virtual Test Range (VTR). The VTR is based on a Silicon Graphics Onyx platform interfaced to a Scramnet global fiber system. The VTR is primarily intended for premission rehearsal.

The DAV serves as the mobile data reduction facility for SMTS. An 8- x 40-foot filtered and signal-isolated van houses a CM-5 supercomputer manufactured by Thinking Machine Corp.

It has been extensively modified for real-time massively parallel operations, performing complex scene analysis and object classification, along with alerting and cuing operations.

Imagery is fed into the CM-5 computer, which differentiates trash, submunitions and pieces of the carrier. Through triangulation of different sensors on different platforms, the location of objects of interest can be determined.

The post-mission data reduction of optics, radar and other sensor data input from SMTS is also performed on the CM-5 platform. The EMOTR is a passive phased array operating in C band that has been modified to handle 40 objects simultaneously.

The SMTS optical data-acquisition system includes visible as well as IR high-density and high-framing-rate focal-plane staring arrays. These cameras were tailored by Sarnoff for SMTS.

The camera is unique in that it does not "bloom," a condition that occurs when too much light overloads the sensors and only a big blob of light registers on the screen. Traditional IR sensors white out the screen when they see the back end of a missile because there's too much light for the sensors to handle.

Sarnoff's cameras enable the team to see detail in the cold body of a missile while tracking a hot missile plume. The camera's framing rate and resolution from has been compared to the resolution of a black-and-white photograph.

Sarnoff is still working to provide a histogram board that will automatically adjust the gains and offsets to give them optimum contrast on the camera. Visible imagery can be taken from one camera and IR from another, and the best of the two outputs can be combined to obtain the best contrast from both visible and IR.

The camera's advanced capabilities with image stabilization are evident. It took an image from what was supposed to be a stabilized optical platform on a helicopter that had a strong jitter, recording the video directly from that platform. With the camera, the image went from jittery to rock solid, all without having to stabilize the platform itself.

Post-mission analysis

Now, the digital output in the focal planes is used primarily for post-mission data analysis. This is where all the intricate edge detail and orientation data, and critical time, space and position information are extracted after the mission, largely by a computer-based image-enhancement technique. The signal-processing activity can be broken into Category A, real-time, and Category B, non-real-time, post-mission. Most of the digital information currently resides in Category B. Film is being phased out as the medium of choice for recording test data because it has several inherent drawbacks. Because it's a solid medium, it's temperamental: exposure must be right, and it depends on a high-precision, expensive mechanical device to feed it. Also, film cannot be reused. Moreover, there are development and storage costs.

The goal of the program is to start the process leading to the elimination of film cameras and their associated costs. The consensus of the White Sands crew is that technology is moving in the digital direction and even Hollywood will eventually replace film and do everything digitally.

The TRW Ramcube's ability to acquire digitally the appropriate frame rate along with the required spatial resolutions, eliminates film.

In addition to the obvious advantages of not having to develop the film and go to all that expense and environmental nuisance, the film data does not have to be reduced. Even if everything was working the way it should—and focus, atmospheric conditions and the stops were correct—much of the accuracy would be lost during the digitization step.

In addition, in an explosion all kinds of trash comes out along with the objects of interest. The enhanced object recognition will enable the team to find those objects and ignore the others, allowing it to look at things it never has been able to examine before.

Ramcube recording

Direct solid-state recording of digital images is accomplished by TRW Ramcube 26G storage devices provided by TRW Systems Integration Group. TRW is also developing the visible and IR camera interface for the Ramcubes.

Real-time morphological transformations can be performed on the visible and IR images using these data files to create an image superspace, in which desirable features of both cameras are combined into a single scaled and oriented image.

> The goal is to start the process leading to the elimination of film cameras.

The real-time digital data is stored in the Ramcube, where it can be retrieved for a thorough and exhaustive analysis.

Sensor fusion is critical to the real-time problem. Signal processing can be divided from an engineering perspective into two regimes: the real-time problem, which is primarily one of command and control acquisition, and the non-real-time problem, which relates to data storage and post-mission data analysis.

There are two data streams coming off the cameras at the same time. One is an analog signal, which finds its way into the real-time command and control problem, and the second is at a much higher rate. It is primarily in that area that the data interface and storage medium of the Ramcube have played a critical role.

The Ramcube takes the video from visual sensors and stores the high-speed digital data coming from the cameras. After three to four months of qualification tests, this system will be fully operational.

Fast analysis

The advantage of using the focal planes directly is that there is no digitization required of the focal plane data, ensuring rapid data analysis. It is already coming out digitally as accurately as the focal planes can provide. They will be able to frame up to 180 frames/second at full resolution and up to 300 frames/s at a lower resolution—which is currently unfeasible with standard off-the-shelf video equipment.

Realistically, a tape drive couldn't begin to keep up with the high-speed data fed directly into the CM-5. Without the Ramcube, there would not be a way to record and retrieve data for later analysis. The post-mission analysis will be able to provide extremely accurate information of an object's position in space down to centimeters.

In the foreseeable future, not only storage of all data but the data processing will be done in real-time.

With the right lens combination and proper sighting of the tracking mount, these unique focal planes from Sarnoff combined with TRW's interface and storage medium will provide much greater accuracy and faster turnaround time than is possible with film.

This project can set a number of precedents in T&E. Its streamlined management has minimized paperwork through the constant coordination between the endgame users—in this case, the actual customer.

A five-year development like this can end up in the creation of a dinosaur, if in the process the evolution of the customer base has dramatically changed, especially in light of a more technically demanding future, driven by the tendency to make smaller, more sophisticated and more effective weapons systems.

This project has relied extensively on the use of a commercial standard and commercial off-the-shelf (COTS) hardware and software, which at times had to be modified. In fact, Sarnoff's camera was discovered at a trade show.

In terms of other applications to commercial industry, the team members agree that a number of industries that can take advantage of the TRW Ramcube technology, such as providing video on demand.