A Case Study:
3D Laser Scanning and
Ballistic Trajectory Analysis
in Officer Involved Shooting

3D Laser Scanning and Ballistic Trajectory Analysis

3D Computer Simulations and Analytical Techniques based upon forensic evidence to accurately reconstruct and illustrate an event.

The Challenge

How to use the physical evidence captured at the scene of a fatal shooting to determine the shooter's position relative to the victim, the victim's positioning at key moments during the event and finally reconstruct the event with sufficient fidelity to the forensic evidence to successfully have the resulting 3D animation admitted into trial.

The Solution

Perform bullet path analysis with sufficient accuracy to locate the shooter's position through the use of a Leica Geosystems ScanStation 3D laser scanner. Precision Simulations (PSI) deployed a Leica ScanStation at the request of the Yolo County District Attorney's Office to assist the California Department of Justice with their investigation of the crime scene. 3D laser scanning enabled PSI to precisely document the crime scene as well as the bullet-riddled patrol car in order to create a 3D Working Model of the scene. Combining the 3D Working Model with the audio and video captured from the camera system in the deputy's patrol car enabled PSI forensic reconstructionist Craig Fries to devise several ground breaking new analyses that clearly showed the defendants claim of self-defense did not match the physical evidence.
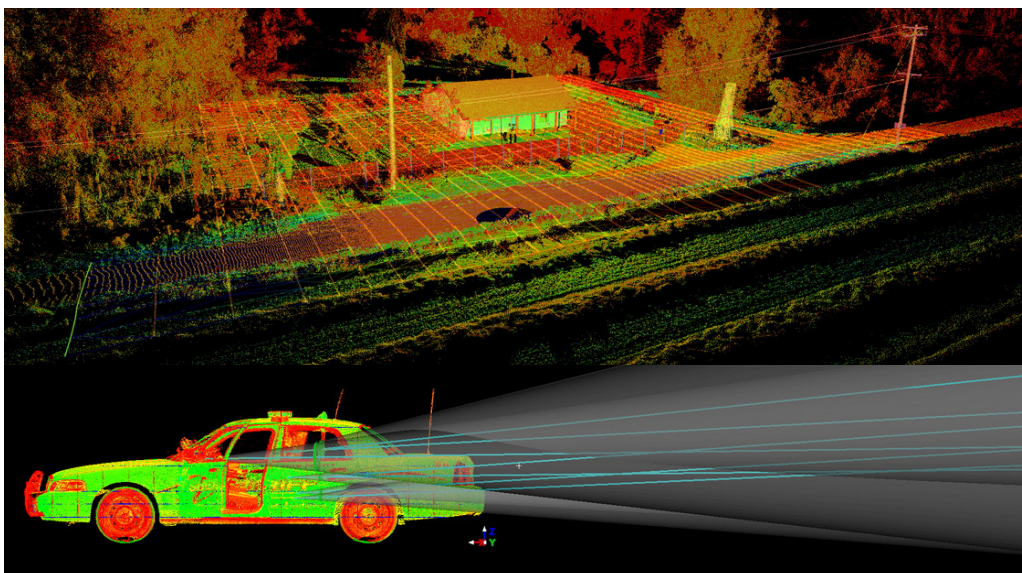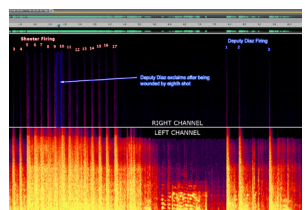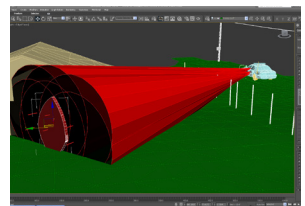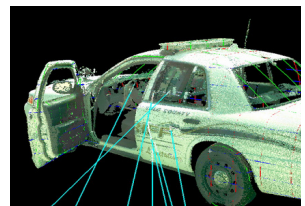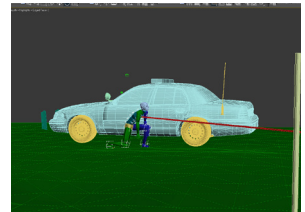
3D Laser Scan data of crime scene and patrol car

The Crime

On June 15th, 2008 Yolo County Sheriff's Deputy Jose Antonio "Tony" Diaz was fatally shot after a high-speed pursuit of Defendant Marco Topete. Topete was found guilty in Yolo County Superior Court of Murder, and the Yolo County D.A.'s office is asking for the death penalty.
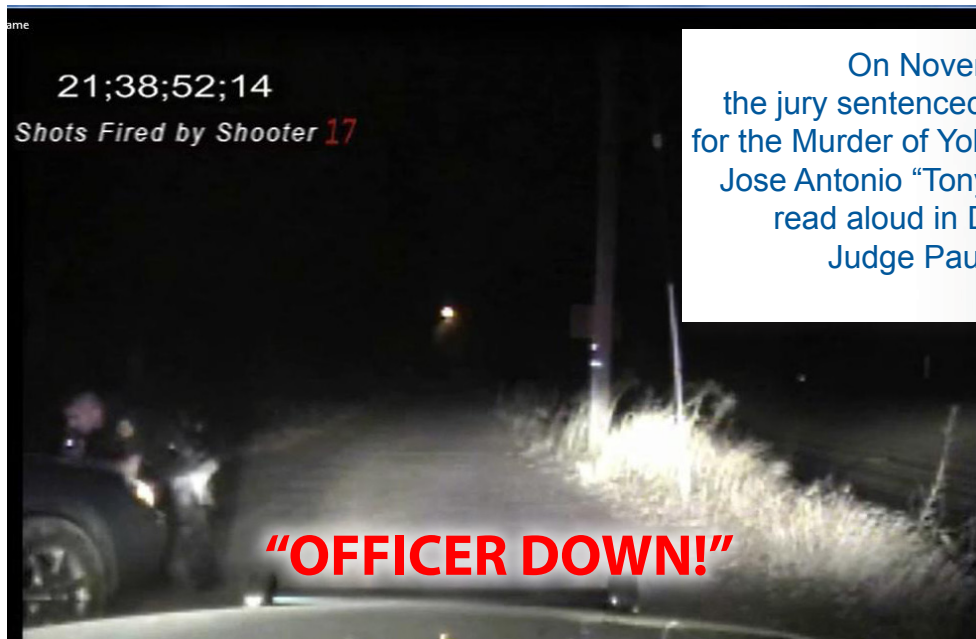

DoJ Evidence marker:Center of cartridge casings at crime scene

Yolo County patrol car with ballistic trajectory rods inserted

Cartridge casings found at the scene indicated that the shooter had fired seventeen .223 caliber rounds from an AR-15 assault rifle at Deputy Diaz. One round pierced Deputy Diaz' Kevlar vest fatally wounding him as he was watching over Topete's young daughter who Topete abandoned in his vehicle after fleeing on foot.

On November 16, 2011, the jury sentenced Marco Topete to death for the Murder of Yolo County Sheriff's Deputy Jose Antonio "Tony" Diaz. The verdict was read aloud in Department 3 before Judge Paul K. Richardson.

Video image and transcript from Deputy Diaz' patrol car camera as he radios for help

PSI's Chairman and Founder, Craig Fries, was the final witness for the prosecution. Mr. Fries was successful in getting an animated reconstruction of the event admitted into trial, along with a 150 slide PowerPoint presentation that clearly laid out the scientific foundation for the animation. The multiple segment animation depicts the vehicular pursuit of the defendant and concludes with an animation of the shooter firing 17 rounds from the assault rifle at Deputy Diaz. In the animation, the Sheriff's Deputy is standing near his patrol vehicle 70 feet away with his back turned as the shooter is shown taking aim from behind a nearby house, pulling the trigger 17 times.

*Artists sketch of PSI's Craig Fries testifying at trial*

Clip from 3D Animation shown at trial depicting Topete opening fire on Deputy Diaz while his back is turned

Analysis Method

PSI utilized an array of technologies in performing the reconstruction including 3D Animation, 3D Laser Scanning and Audio Frequency Analysis . Mr. Fries testified extensively on the methods used to determine the following:

- The location of the shooter behind the corner of house, 70 feet from Deputy Diaz
- The location and orientation of the AR-15's muzzle when the 17 rounds were fired
- The location and orientation of the deputy's patrol vehicle
- That Deputy Diaz had his back turned to the shooter at the time the shooter opened fire
- Which round in the sequence of 17 fired fatally wounded Deputy Diaz
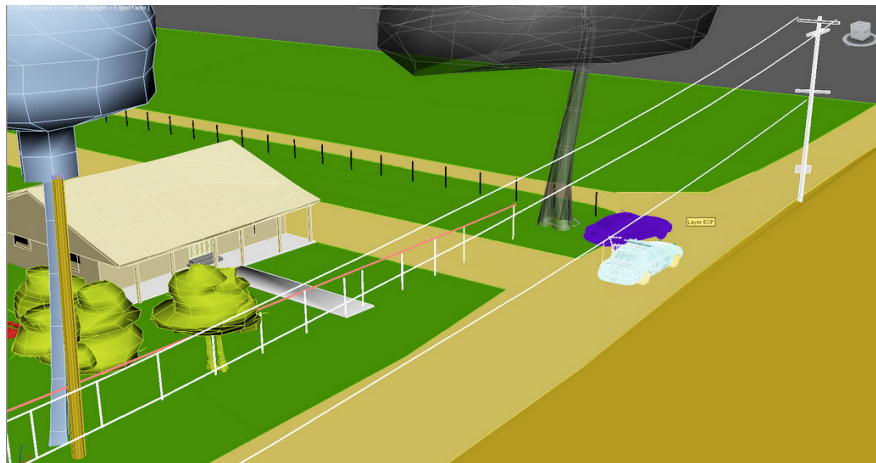
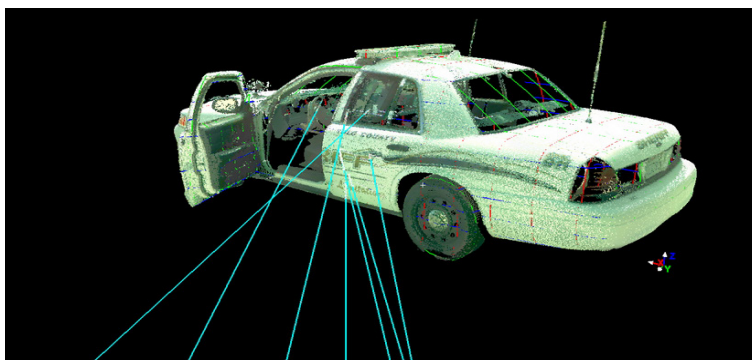*3D model of crime scene derived from Laser Scan data*

3D Laser Scanning

PSI pioneered the use of 3D laser scanning forforensic analysis in the late 1990's and has been at the forefront of its use in accident and crime scene documentation and reconstruction analysis. PSI used the Leica GeoSystems ScanStation system which was praised by Mr. Fries for its accuracy and the internal dual-axis compensator which captures the leveled survey quality data required for sophisticated analysis and physics based crime scene reconstructions. It has the added benefit of being able to create visually compelling exhibits for a Jury's ready comprehension.

Laser Scanning Ballistic Trajectory Rods extending from the Patrol Vehicle

PSI worked alongside a qualified firearms examiner from California Department of Justice's Sacramento Crime Laboratory as they inserted ballistic trajectory rods into multiple bullet holes left in Deputy Diaz' patrol vehicle. Using the ScanStation 3D laser scanner to measure these rods guaranteed the most accurate data and analysis possible.

*Leica ScanStation II measuring Patrol Vehicle with Ballistic Trajectory Rods inserted into bullet holes*

3D Model of Patrol Vehicle and Ballistic Trajectory Rods from Laser Scanning Data showing the direction of the multiple AR-15 rounds fired at Deputy Diaz

Documenting the Crime Scene with the 3D Laser Scanner

In addition to the deputy's patrol vehicle, PSI used 3D laser scanning to thoroughly and accurately document (map) the crime scene. An accurate 3D model was critical to the success of the reconstruction, providing PSI with a virtual model of the scene and allowing very detailed analysis of the bullet trajectories within the scene. The ability of the ScanStation to capture fine detail at long range was key to being able to laser scan the subject house from the public roadway as the occupant was clearly agitated by the activity and would never have allowed access to the property.


3D Laser Scanning Data of the Crime Scene
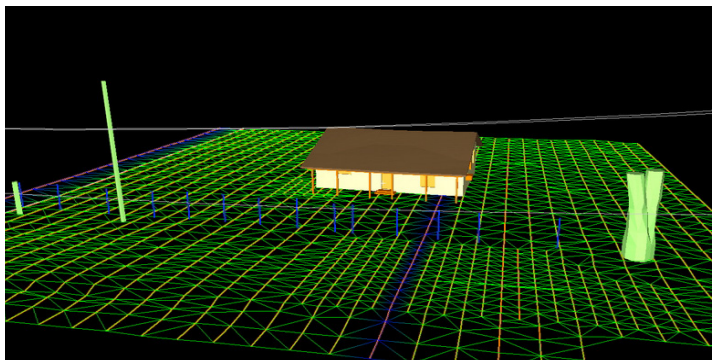
*3D Model of Crime Scene derived from Laser Scanning*

# Determining Shooters Location behind House from Ballistic Trajectory Analysis

Once the physical evidence had been meticulously documented with Laser Scanning, PSI developed a ground breaking new method of scientific analysis to determine the shooter's position. This new method showed conclusively that Topete had taken a position behind the corner of a neighboring house, 70 feet behind Deputy Diaz.
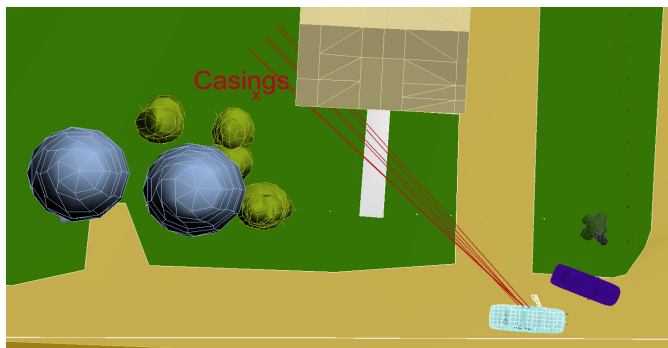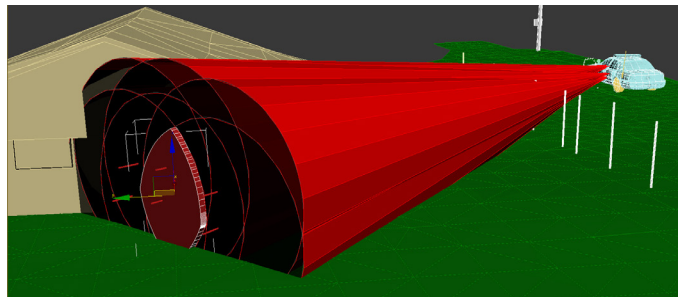

Top Down View of 3D Working Model of Crime scene with Vehicles and Ballistic Trajectories shown
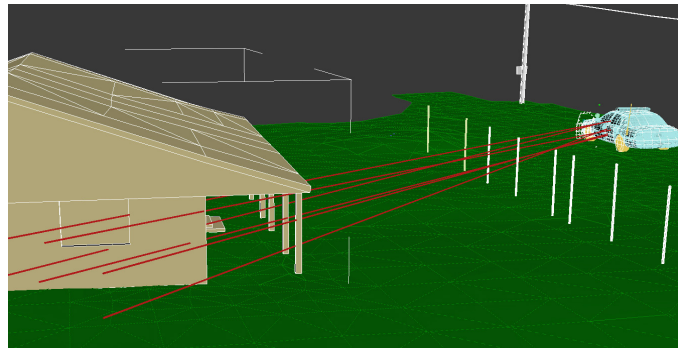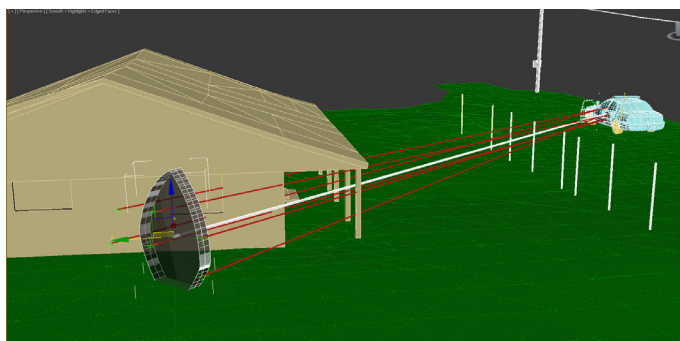

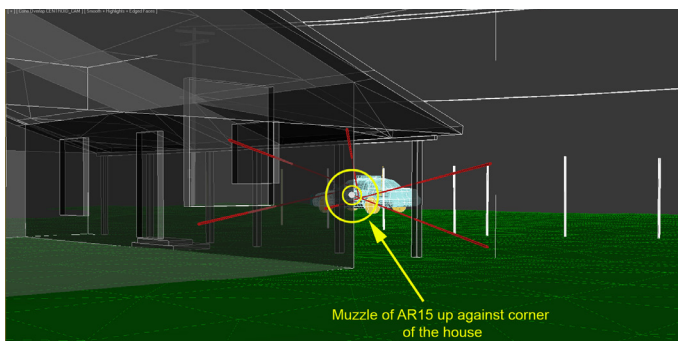*Perspective View of 3D Working Model of Crime scene with Vehicles and Ballistic Trajectories shown*
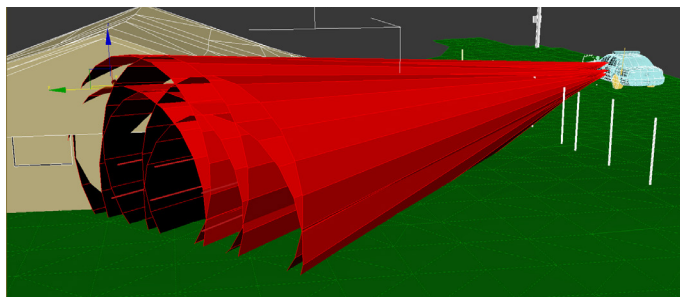
Plus or Minus Five Degree Cones of Possibility

Overlap of 5 degree cones isolates Topete's position in the "football shaped" area

Center of Overlap = Shooter's most likely position

Shooter's perspective View – Note the muzzle alignment with corner of house

Once the 3D model of the patrol vehicle with the virtual ballistic trajectory rods extending from it was positioned within the 3D crime scene, the location and orientation of the AR-15 was determined by using a revolutionary new method. Each bullet trajectory was assigned a +/- 5 degree cone of uncertainty which takes into account the error rate for this type of analysis. Mr. Fries then computed the common area where the six trajectories overlapped in 3D. This common area was the only location where the shooter could have been to have left behind the pattern of ejected cartridge casings and match all six bullet trajectories.
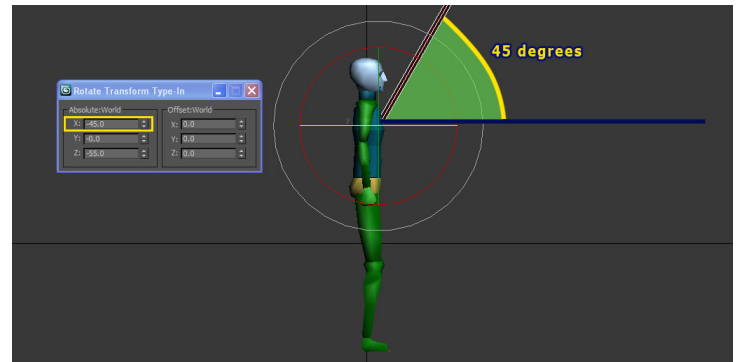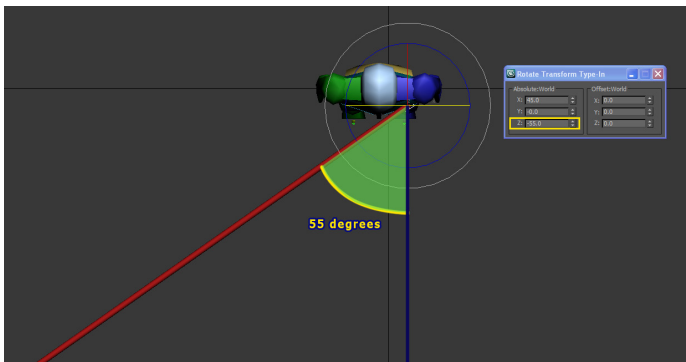
Ballistic Trajectory Analysis of Fatal Round

The final ballistic analysis involved determining the body position of Deputy Diaz when he received the fatal .223 round through the front of his Kevlar vest. This was a critical area to analyze given that early analysis of the evidence indicated that Deputy Diaz was standing with his back turned to Topete when the first shots were fired. This was corroborated by PSI's analysis.

The Department of Justice's Crime Lab issued a report stating that the round that went through Deputy Diaz vest came "from the Deputy's right to left at a 55 degree angle…and from top to bottom at a 45 degree angle".

PSI created a 3D model based upon Deputy Diaz' measurements then computed and illustrated 3D ballistic trajectory that matched the 55 degree 45 degree angle specified in the DoJ report.

Deputy Diaz' kevlar vest with location of fatal bullet entry

3D model of Deputy Diaz with ballistic trajectory created from Department of Justice report data

The model of Deputy Diaz was inserted into the 3D crime scene and moved around until the trajectory of the fatal round was aligned with the (now) known location of Topete. The result demonstrated that Deputy Diaz reacted to hearing the first shots by turning approximately 180 degrees and crouching near his patrol car, in keeping with his tactical training to "get small" when fired upon.
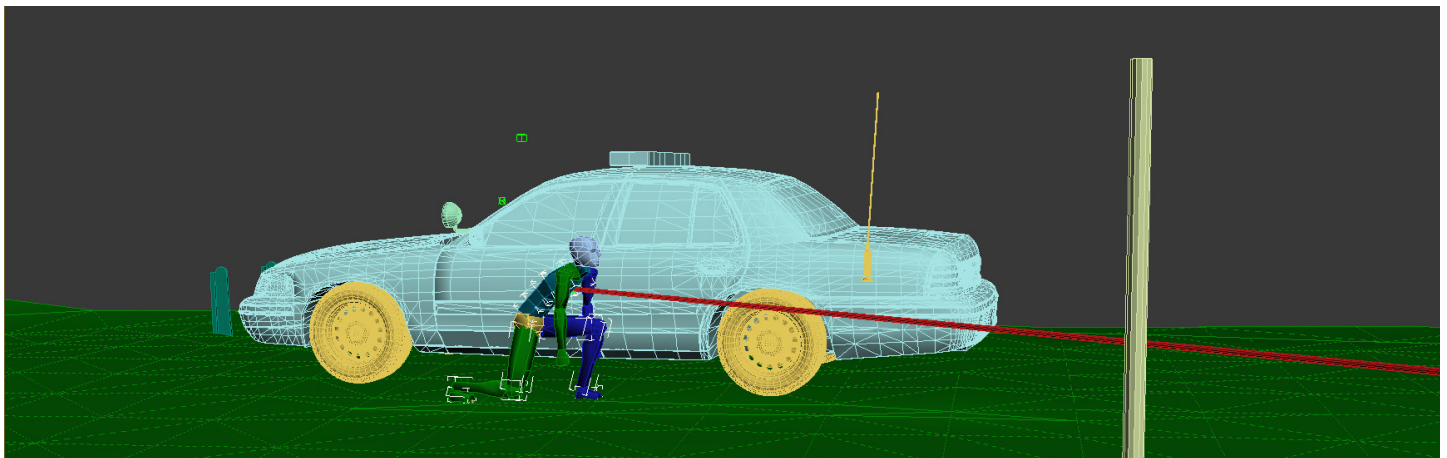
Location and body posture of Deputy Diaz at time fatal 8th round struck him in the chest

Analysis of Audio & Video from Camera Mounted in Deputy Diaz' Patrol Car

PSI analyzed the video of the event as captured by the camera mounted inside Deputy Diaz' patrol car. Although the shooting itself was not caught on tape, the audio of the event was, and this provided PSI with critical evidence needed to determine:

- That Deputy Diaz had his back turned to Topete when Topete started firing
- That Deputy Diaz was fatally struck by the eighth out of the17 rounds
- That Deputy Diaz spun around and crouched low to the ground in response to the shots fired at him resulting in his being struck in the chest

These critical facts put to rest any defense claim that the shooter fired in self-defense, as Deputy Diaz was proven to have had his back turned to Topete when Topete commenced firing. It also explained how the fatal round came to penetrate Deputy Diaz' front side.
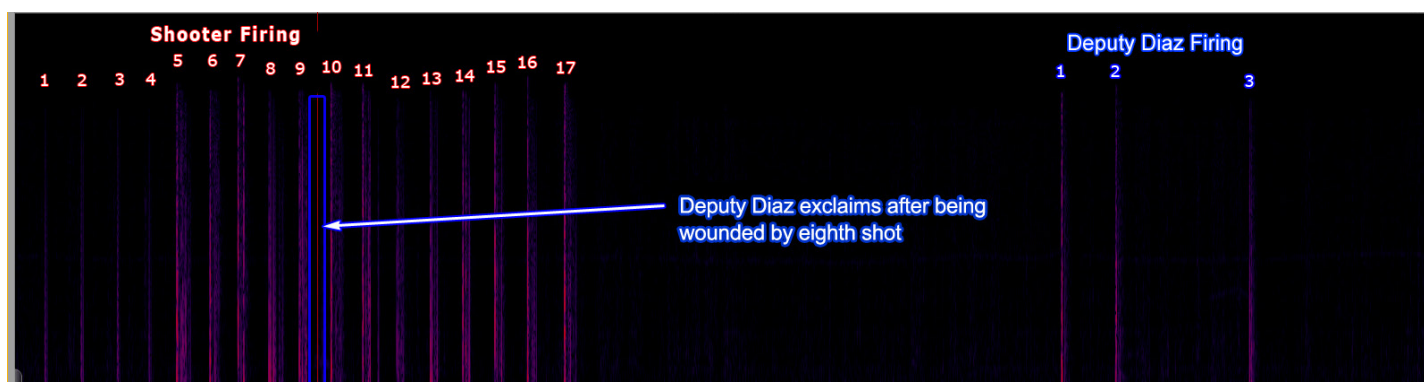
Frequency Analysis of the audio from patrol car camera system depicting the timing of each event

SHOOTER	SHOT #	TIME - Analysis	TIME - Norm	Time - Delta
Shooter	1	0.24	0.00	na
Shooter	2	0.51	0.27	0.27
Shooter	3	0.77	0.53	0.26
Shooter	4	1.01	0.78	0.24
Shooter	5	1.22	0.99	0.21
Shooter	6	1.47	1.23	0.25
Shooter	7	1.68	1.44	0.21
Shooter	8	1.92	1.69	0.24
Shooter	9	2.14	1.91	0.22
Deputy Diaz	"EXCLAIMS"	2.28	2.04	0.14
Shooter	10	2.38	2.14	0.24
Shooter	11	2.62	2.39	0.24
Shooter	12	2.89	2.65	0.26
Shooter	13	3.13	2.90	0.25
Shooter	14	3.37	3.14	0.24
Shooter	15	3.62	3.38	0.25
Shooter	16	3.86	3.63	0.24
Shooter	17	4.15	3.91	0.28
		TOTAL TIME	*3.91*	
		Avg Time/shot	*0.244*	

Timing data derived from Audio Frequency Analysis for each shot and Deputy Diaz' exclamation of pain in response to eighth round striking him in chest

"*PSI's excellent and sophisticated analysis proved conclusively that the defense version of events was invalid; their reconstruction presented these facts in the most compelling and persuasive manner possible, Mr. Fries' trial testimony was among the most professional I have ever witnessed and was best received by the jury.*"

- Yolo County DA, Jeff Reisig

Clip from the 3D Animation shown at trial. The multiple images show two views of the animation synchronized to the audio and video from the patrol car's on-board camera system. This clip illustrates the event at the time the fatal Eighth round is fired by defendant Topete and strikes Deputy Diaz in the chest.

Topete Trial: Jury Sees Simulation of Deputy's Death

Judge Says Video Is 'Reasonably Close' To Reality

David Bienick/KCRA - POSTED: 12:17 pm PDT September 7, 2011

WOODLAND, Calif. -- Jurors saw a computer simulation Wednesday that attempts to fill in some of the gaps of how Deputy Jose "Tony" Diaz was killed.

The simulation was produced by Craig Fries, of Precision Simulations, Inc., who said the presentation is based on the video provided by the dash camera in Diaz's patrol car and physical evidence gathered at the scene.

That video does not show Diaz being hit, nor does it show who pulled the trigger.
Yolo County Superior Court Judge Paul Richardson warned jurors, before the simulation was shown, that it was "only designed to be an aid" and "not intended to be a film of exactly what occurred."

However, Richardson said the simulation was "reasonably close."

The simulation shows Diaz standing near the driver's side of his patrol car on a dead-end road near Dunnigan. It shows a shooter positioned at the corner of a nearby house who fires 17 shots with an AR-15 assault rifle.

According to the simulation, Diaz had his back to the shooter when the shots started, then turned to face the gunfire and was hit by two bullets to the chest. One of the shots pierced Diaz's bulletproof vest, entered his chest and killed him. "Deputy Diaz's back is turned when the shots first rang out," said Fries.

The distinction is important because prosecutors are trying to prove that defendant Marco Topete was out to kill a cop that night in June 2008 and was not simply fleeing from a possible drunken driving arrest. If convicted, Topete faces a possible death penalty.

Family members of Diaz cried quietly and wiped their eyes as the simulation played. Deputy District Attorney Garrett Hamilton told the judge that he expects Fries to be the prosecution's final witness.

Media Insert

Diaz shooter was 70 feet away

Judge may watch Topete's confession in chambers

By KATHERINE JARVIS / Daily Democrat

Created: 09/08/2011 12:30:46 AM PDT

The shooter who murdered Yolo County Sheriff's Deputy Tony Diaz was about 70 feet away from him when the 17 shots were fired, according to testimony Wednesday in the Marco Topete trial.

Topete, 39, is charged with murdering Diaz June 15, 2008 on County Road 5 in Dunnigan. He could face the death penalty or life in prison if convicted. Topete has pleaded not guilty to all counts.

In one of the last pieces of the prosecution's case against Topete, Craig Fries, of Precision Simulations, presented a 3D animation video, reconstructing the shooting through laser scanning of the scene and Diaz's patrol car. He used six of the seven trajectory marks that were on Diaz's patrol car from shots fired, as well as the shell casing from the gun, an AR-15 assault rifle, to determine where the shooter was located.

According to Fries' estimation and the work of forensic engineer Robert Cargill, who conducted test firing, the shooter was at the southwest corner of Jesse Gonzales' house on CR-5 and shot through the porch toward Diaz's vehicle. Cargill testified two weeks ago.

Fries agreed with Cargill's previous opinion that Diaz was in a "crouched and bent position" when he was shot.

In addition, Fries said Diaz had his back turned when the shots began firing but turned to face the shooter with a bullet penetrating the top of his Kevlar vest, above his heart.

The dashboard camera video from Diaz's patrol car was used to recreate the scene. The video shows the scene in front of Diaz's car but does not show the deputy being shot. However, audio of the 17 shots can be heard along with a yell from Diaz as he was shot and him saying over the radio "officer down."

√PSI