



TRC1104

**Use of Unmanned Aerial Vehicle for
AHTD Applications**

**“Studying Visual Aids to Assist in
Corridor Analysis”**

Tymli Frierson

Final Report

2013

Arkansas State Highway & Transportation Department
Transportation Research Committee

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USE OF UNMANNED AERIAL VEHICLES
FOR AHTD APPLICATIONS

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**TRC 1104
Use of Unmanned Aerial Vehicles for AHTD Applications
“Studying Visual Aids to Assist in Corridor Analysis”**

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CHAPTER 1

INTRODUCTION

As part of its mission to develop, operate and maintain a safe and efficient transportation system, the Arkansas State Highway and Transportation (AHTD) monitors, inspects and surveys its highways, bridges and facilities. Outside of surveying, this is done in many other ways, such as the Automated Road Analyzer (ARAN) vehicle, traffic counters, bridge sensors, cameras and field or site inspections. However, there is a need to view areas from a bird's eye view in a flexible, safe and cost-effective manner. This ability could be beneficial to the Environmental Division, the Arkansas Highway Police, the Maintenance Division, the Transportation Planning and Policy Division, the System Information and Research Division, the Public Information Division, the Right of Way Division and AHTD District Personnel. By recording High Definition (HD) video from varying altitudes, AHTD staff can collect real-time movement of traffic while in the field. This ensures proper data collection before returning to the office.

Previously, aerial imagery consisted of fly over photos limited to a specific time or telescopic mounted cameras with limited viewing angles, both of which are cost prohibitive. With advancement in technology, AHTD is now able to examine other equipment that provide an economical and feasible solution with the versatility needed to adapt to different data collection situations. The availability of High Definition video, High Definition pictures, low light visibility and thermal imagery at a fraction of the cost of alternative solutions warrant an investigation into the possible uses of other video

equipment for recording turning conflicts, number of vehicles, headways, queues and vehicle classification. This research was done to examine data collection equipment that will not only be useful to to correctly model real-time traffic movements, but also to better design roads in the state of Arkansas in a cost effective way.

CHAPTER 2

LITERATURE REVIEW

A review of literature was conducted to identify research concerning other ways to collect traffic data from a bird's eye view. Details of literature that were of assistance in regards to equipment that could be used for this research project are provided below.

EQUIPMENT

Unmanned Aerial Vehicle

The Unmanned Aerial Vehicle (UAV), also known as the drone, is an aircraft that is operated without a human being on board (Figure 1). It is controlled by a pilot operating a remote control on the ground or autonomously by computers in a vehicle. The UAV is said to be a flexible and a cost-effective approach to collecting real-time data from a bird's eye view over intersections or other large areas. UAVs have become more popular over the last couple of years in transportation planning, engineering and operation, and several options and designs have entered the market. UAVs are able to carry cameras or video cameras, and their use in data collection can be expected to improve traffic management. However, there are restrictions when using the UAVs that limit the use of operating a UAV to collect traffic data. The main restriction is that of the Federal Aviation Administration (FAA), which limits the use and research of UAV applications. The FAA Modernization and Reform Act of 2012 was introduced in on February 11, 2011 and signed by the President of the United States on February 14,

2012. It includes important provisions on the integration of unmanned aircraft systems (UAS) into the national airspace system.



Figure 1. Unmanned Aerial Vehicle (Source: DraganFly)

A few states have studied the UAV for traffic data collection, including static remote sensing images and real time traffic information. Studies also include UAVs route planning and strategies of path-planning for a UAV to track a ground vehicle (PB Farradyne 2005).

Recently, newer applications are being studied, and the government is also looking into the feasibility of UAVs for transportation. The Utah Department of

Transportation (UDOT) used UAVs to monitor and document State Roadway structures by taking advantage of high-resolution aerial photography (Steve Barfuss et. al 2012).

UAVs have potential to become a great application for collecting traffic data. However, with FAA restrictions and the time schedule for this particular project, UAVs were not applicable for AHTD at this time.

Lighter-Than-Air-Surveillance

Aerial Products, a company specializing in aerial photography and surveillance equipment, has a Lighter-Than-Air-Surveillance (LTAS) series that employ a unique combination of Commercial Off The Shelf (COTS) and military technologies with ground breaking operational methods. Below are two examples of LTAS systems suitable for this project.

LTAS Mast Surveillance

According to Aerial Products, using a mast or pole is one of the most cost-effective means for elevating a camera to record a video or photograph from a bird's eye view. Models range from 20 feet to 100 feet high with head-load ratings from 15 to 120 pounds. The overall operation of this equipment is simple, allowing anyone to use it with some simple training. Setting up the equipment takes up very little room, leading to more available setup locations. Packages can be engineered for specific mission-sets, such as mobile border patrol, perimeter security, crowd management, emergency incident responses situational awareness, communications relay, check points, etc. Mounting options include vehicle 2" hitch, command vehicle integrated, field-stand, or

trailer tilt-over. The mast extension options are either belt or pneumatic. Organizations such as US Border Patrol, US Army or US Marines use belts masts because of its advantage of low maintenance in high-dust environments. Pneumatic mast models are used by highway departments for traffic monitoring, forestry services, first responders and police. Pneumatic models are lighter weight and are typically used when heights exceed 50 feet.



Figure 2. LTAS Mast Surveillance

LTAS Aerostat Surveillance

According to Aerial products, LTAS Aerostat Surveillance provides solutions for persistent airborne surveillance without the failure rate of typical UAVs. They are flexible and operate up to 2,000 feet. The LTAS 75 -100 systems can be used for the following:

- municipal deployments
- crowd management
- incident response
- other heightened security situations where aerial surveillance provides situational awareness, a force multiplier, command and control and evidential video and
- traffic monitoring.

The LTAS 75-100 series includes a range from highly tactical to completely self-controlled. The highly tactical system consists of using a hitch mount winch (Figure 3) that launches the balloon (Figure 4).



Figure 3. 12 volt DC electric winch



Figure 4. LTAS Aerostat Surveillance Launched

The pictured system is the LTAS 75, which is a low-cost system that operates up to 450 feet. Standard features include:

- Portable, electric 24 volt DC winch system, variable speed
- Vehicle receiver hitch mount for winch, batteries, inverter package
- Power and data tether
- Payload and laptop power inverter with separate battery
- Vehicle 7-pin harness charging system
- 1-ply Kingfisher aerostat, model K14U-SC balloon
- FAA approved automatic GPS deflation device
- Laptop controller with Hall-effect joystick
- 24 hour DVR (software, pre-loaded on laptop)
- Single-sensor, gyro-stabilized UAV camera gimbal
- 2-days factory training (1 day classroom, 1 day field)
- Aerostat inflation system
- Spares kit; aerostat patches, fly-lines, payload lines

Standard features for the LTAS 100 System includes:

- Expanded launcher for (4) additional Helium tanks
- Additional single-sensor camera gimbal; Daylight EO or Thermal LWIR
- Dual-sensor camera gimbal; EO+LWIR
- Extended operating altitude; + tether and larger Kingfisher aerostat
- Simultaneous video downlink to mobile viewing station

CHAPTER 3

WORK PLAN

The primary objective of this research project was to find a way of monitoring traffic in a flexible, safe and cost effective manner. This was done by testing the above literature to see which of the two LTAS systems will produce the same type of information as does the UAV for AHTD applications. Though the project initially focused on a UAV, other equipment was researched due to restrictions on the UAVs, such as minimal loft time, multiple batteries needed, payload limitations, FAA requirements and retrieving a Certificates of Authorization, which is an authorization issued by the Air Traffic Organization to a public operator for a specific Unmanned Aircraft activity.

Locations were evaluated. Video footage of traffic flow was collected and collated using VisSim software. The value of the data obtained was determined following the collection of data. A demonstration of the UAVs practices for a police department was shown, and a demonstration of the LTAS equipment was shown by a sales representative, Kevin Hess.

After reviewing the literature, it was decided that the 2 systems that would be used for this research project were the mobile mast camera system and the tethered helium balloon system.

CHAPTER 4

DATA COLLECTION

The most critical step in an analysis process is data collection. One must know what, where, when and how long to collect. You must also know how to manage the data. Data collection for this project varied depending on the needs of the study for which the data was being collected for at each location. The purpose of the field data collection was to see if the equipment used was feasible enough to provide AHTD with clear visible footage to reduce data for simulation modeling and any other needs.

A pilot test was done at the AHTD Central Office to determine time and manpower requirements to set up equipment and the amount of space needed for data collecting.

The first step in obtaining data was to locate an area that would be suitable for collecting data at the study site. This was done by finding possible locations surrounding the test site on Google maps and examining these locations in the field prior to setting up equipment. Though both pieces of equipment were used for the same purpose, the setup was different for each. Below, both setup processes are briefly described.

EQUIPMENT SETUP

Tethered Helium Balloon Camera

Prior to launching, helium needs to be purchased. Based on the pilot test, a minimum of 4 people are needed to set up the tethered helium balloon. If the day is

windy, more people will be needed, which is why calm days are strongly recommended. It takes approximately 30-45 minutes to set up. The launch site would have to be large and obstruction free and due to FAA regulations, the tethered balloon cannot be launched within 5 miles of an airport.



Figure 5. Tethered Helium Balloon Setup

Mobile Mast Mounted Camera

Based on the pilot test, a minimum of 2 people are needed to set up the mobile mast mounted camera. It takes approximately 15-20 minutes to set up. Setting up this equipment takes very little room, which leads to more available setup locations at each project site. However, making sure to account for space needed to place the guy wires and making sure there are no power lines nearby are not within falling distance of the pole are essential.



Figure 6. Setting Up Pole for Placement



Figure 7. Mounting the camera to the pole



Figure 8. Securing the Mast

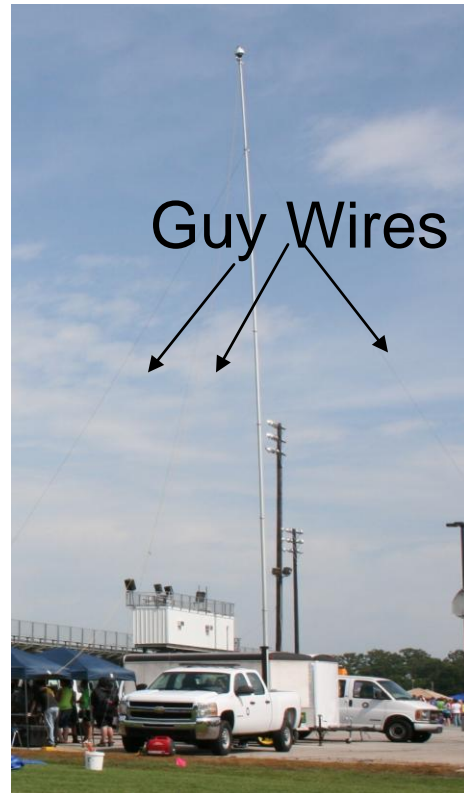


Figure 9. Pole Extended with Guy Wires

FIELD DATA COLLECTION

All data collected were of current studies throughout the highway department. Figure 5 shows a map of where the equipment was deployed. Due to issues with launching the tethered helium balloon, data collected using this equipment was limited.

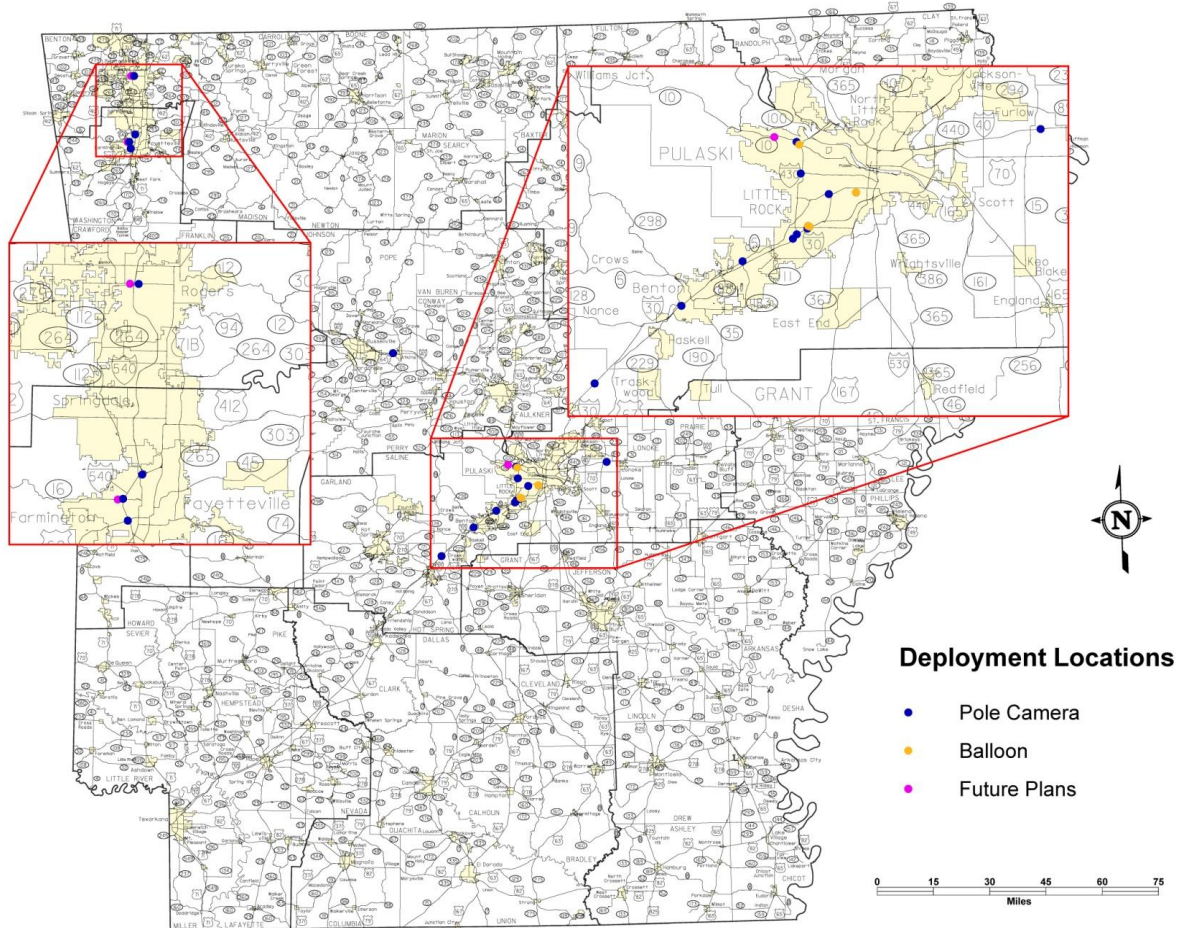


Figure 10. Deployment Locations for Equipment Use

Table 1 shows a summary of each study. As shown in the table, the equipment that was used was the mast mounted camera. However, please note that the helium balloon was launched several times to see if it was applicable for the study. Due to

limited space, wind and other problems, the balloon was not feasible at most locations that were chosen to collect data. See Appendix A for detailed information on each study.

Table 1. Studies Using Mast Mounted Camera

STUDY	LOCATION	REQUESTED BY	DATE	EQUIPMENT USED	REASON
Highway 5 Widening Study	Intersection of Highway 183 (Reynolds Rd.) and Highway 5 in Bryant, AR	Planning and Research Division, Statewide Planning Section	3/9-10/2011	Mast Mounted Camera	Monitor traffic signal & queuing at intersection; determine if NB traffic in the outside lane is blocking inside lane
I-540/Highway 112/Highway 71B Interchange Justification Report	I-540/Highway 112/Highway 71B Interchange near I-540 Exit 66 in Fayetteville, AR	Planning and Research Division, Statewide Planning Section	3/15/2011	Mast Mounted Camera	Determining number of people weaving on I-540 SB between Hwy 71B entrance ramp & the Hwy 112 exit ramp; operational analysis for the reconfiguration and improvement of I-540 and the interchange area
Hwy 10 Corridor Study	Intersection of Highway 10 and Rodney Parham Rd. in Little Rock, AR	Planning and Research Division, Statewide Planning Section	3/23/2011	Mast Mounted Camera	View traffic movements; needed to see vehicles movements from I-430 SB to Hwy 10 WB to left on Rodney Parham Rd.
I-30/I-430 Interchange Study	I-30/I-430 Interchange in Little Rock, AR	Planning and Research Division, Statewide Planning Section	5/3-4/2011; 5/26/2011; 3/13/2012	Mast Mounted Camera	Model the traffic patterns; used camera footage in place of attempting volume count data collection on the multi-lane freeway; needed to see the origins and destinations within the weave on I-30 WB between I-430 SB and Otter Creek off-ramp
Interstate Platooning Study	I-40 near Lonoke, AR, I-40 near Atkins, AR and I-30 near Malvern, AR	Planning and Research Division, Policy Analysis Section	3/25/2011; 5/23/2011; 6/14/2011	Mast Mounted Camera	View platooning characteristics on rural freeways with high truck percentages; counted lane density for 1/4 mile distance
I-630/Shackleford Intersection	Intersection of Shackleford and Financial Center Parkway/I-630 in Little Rock, AR	Maintenance Division	8/8/2011	Mast Mounted Camera	Corridor view of the I-630 approach
Study of Adding a New Access Point at an Intersection	Intersection of Highway 5 (Col. Glenn) and Highway 70B (University Ave.) in Little Rock, AR	Planning and Research Division, Statewide Planning Section	10/4/2011	Mast Mounted Camera	Used video as a calibration tool in the composition of a microsimulation model to study the effects of a new access point on an adjacent signal
Highway 71B Interchange Improvements	Intersection on the East side of I-540 Exit 85 near Rogers, AR	Planning and Research Division, Statewide Planning Section	10/6-7/2011	Mast Mounted Camera	Used to accurately model the traffic patterns occurring in this interchange area
I-540/Highway 16/Highway 112 Spur Interchange Improvements	Intersections on either side of I-540 Exit 62 in Fayetteville, AR	Planning and Research Division, Statewide Planning Section	4/10-11/2011	Mast Mounted Camera	Used to accurately model the traffic patterns occurring in this interchange area
I-540/Highway 62 Interchange Improvements	Intersections on either side of I-540 Exit 64 in Fayetteville, AR	Planning and Research Division, Statewide Planning Section	4/10-11/2011	Mast Mounted Camera	Used to accurately model the traffic patterns occurring in this interchange area

ADJUSTMENTS TO EQUIPMENT

The research team attempted to use image stabilizing software to improve the quality of the videos for the tethered helium balloon, but the results were not good. Some of the videos would not load in the software due to their size, and those that would process did not turn out well. The software worked by matching pixels between frames. This process was to keep parts of the image that did not move in the same relative location (frame-to-frame). However, with as much movement as was observed, the software deleted too much footage, leaving very little stabilized video.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

MOBILE MAST MOUNTED CAMERA

The mobile mast mounted camera appears to be feasible for highway department planning studies and remote observation needs. At a raised height of 58-ft, the mobile mast mounted camera gives a bird's eye view of the area, allowing the user to observe much more than what is possible from the ground. The overall operation of this equipment is simple, allowing anyone to use it with some basic training.

Advantages

- Setting up the equipment takes up very little room, leading to more available setup locations at each project site. The only limiting factors for setup location sizing are the guy-wire anchoring locations, the need to avoid power lines within falling distance of the pole and the overall height itself. If these can be accounted for, and the view from the location is acceptable, the site can be used.
- Several other aspects of this equipment made it easy to use. The articulating hitch-mount utilized for the duration of this project appeared to be acceptable for all operations. This standardized mounting hardware meant that any truck with a 2-inch hitch receiver could be used to deploy the camera.

- Once trained, the computer software was easy to use and did not require constant supervision during filming. The mast system itself was very low-maintenance. It just needed to be lubricated every so often to make sure everything moved smoothly.
- Setup can be done with a small group. Most experiences during this project included a setup team of 3-4 people and an observation and take-down team of two. This many people are recommended because some of the equipment is heavy and it all goes quicker with everyone working together. Although, if needed, this can all be set up by a single person. The research team only tried this once and would not recommend it unless absolutely necessary.

Disadvantages

Even as good as this equipment was, there were still some disadvantages.

- One disadvantage was making sure to have everything before heading out for a job. A checklist of 10 items was made to ensure nothing required for operation was left behind, but with that much equipment, mistakes did happen and important items were forgotten.
- The extended height of 58-ft is another disadvantage. This height just isn't high enough for some applications. This problem was observed at several of the test sites where easy setup locations would have to be passed up because the camera could not get high enough to avoid

obstacles or see over a slight hill. Having a mast 10-20 feet taller may allow for better views.

- Other major disadvantages have to do with the weather. This equipment was made for use in dry weather and thus the camera head and other important connections are not waterproof. This means that any operation in precipitation must be avoided. The fact that this is a 58-ft lightning rod must also be taken into account when deciding when and where to deploy. Even storms in the distance may mean that the mast shouldn't be raised. Wind can also cause problems if it is strong enough to move the camera. A moving camera leads to shaky video that is difficult to watch.

Recommendations

Though the equipment is feasible, it is recommended that a few changes be made to the equipment.

- While the hitch-mount worked very well, some other mounting ideas were discussed. One such idea was to permanently mount the mobile mast onto a trailer with a tilting mechanism to raise it into place. All of the other equipment required for operation could be mounted on the trailer as well, removing the guesswork of gathering everything each time the equipment is deployed.
- Though the computer software is easy to use, the computer operator should "break" the video every hour to keep the file sizes at a more-manageable level.

TETHERED HELIUM BALLOON CAMERA

The tethered helium balloon camera is not viewed as a feasible option for Departmental use. While a view from 500-ft high could be very beneficial to planning studies, the balloon was too unstable and that lead to poor overall image quality. Every slight shift in wind would require an adjustment of the camera, leading to a constant need for the user's attention. This constant attention to detail would become tiresome very quickly and would require a minimum of two people on the observation team so that they could switch intermittently.

Advantages

- Other than a view from 500-ft above, no other advantages were determined.

Disadvantages

Image quality was definitely a drawback for this system. However, it wasn't the only drawback.

- The helium required to launch the balloon, just once, cost \$200-\$300, and since helium supplies are getting low, the cost of helium will only be going up. An attempt was made by the research team to save some of the helium between launches. A polyurethane bladder, made up of the same material as the balloon, was purchased and placed in an enclosed trailer.

All interior surfaces of the trailer were covered in carpet to keep from puncturing the bladder. By pumping helium out of the balloon and into the bladder at the end of the day, the helium could be stored and re-used for subsequent launches (Figure 11). However, attempting to save the helium would also require another vehicle to haul the trailer.



Figure 11. Transferring Helium from Balloon to Bladder



Figure 12. Helium stored in bladder

- Setting up and launching the balloon required a minimum of 4 people and would require more on a windy day. Though, due to the instability in the video, calm days were strongly recommended for launch. The launch site would have to be large and obstruction free and due to FAA regulations, the tethered balloon cannot be launched within 5 miles of an airport. That last point alone greatly reduces the usefulness of the balloon since most studies where this would be needed are in metropolitan areas near airports.
- The system is also not weatherproof. The box containing the camera is not sealed and the cable tethered could act like a lightning rod. Water would not directly damage the balloon, but not allowing it to dry completely before storage could lead to mildew or rot. appearing.

Recommendations

Though it has been concluded that this equipment is not feasible, other options are available to make it feasible, but not economically feasible. In order for the Department to use it, a gyro-stabilized camera to steady the images could be purchased and tested. The money for this type of equipment was not in the project budget.

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APPENDIX A

STUDY SITES

Highway 5 Widening Study/Highway 183



- Location: Intersection of Highway 183 (Reynolds Rd.) and Highway 5 in Bryant
- Date: March 9-10, 2011
- Requested by: Statewide Planning
- How Mast Camera was Utilized:
 - Determine how the traffic signal operated and how much queuing occurred at the intersection.
 - Determine if northbound traffic in the outside lane was blocking the inside lane.

I-540/Highway 112/Highway 71B Interchange Justification Report



- Location: I-540/Highway 112/Highway 71B Interchange near I-540 Exit 66
- Date: March 15, 2011
- Requested by: Statewide Planning
- How Mast Camera was Utilized:
 - Determine how many people were weaving on I-540 southbound between Highway 71B entrance ramp, and the Highway 112 exit ramp.
 - Do an operational analysis for the reconfiguration and improvement of I-540 and the interchange area.

Highway 10 Corridor Study



- Location:
- Date: March 23, 2011
- Requested by: Statewide Planning
- How Mast Camera was Utilized:
 - The camera elevation gave us perspective to view traffic movements that would not be picked up on a typical volume count and that would have been very difficult to observe at ground-level.
 - View vehicles going from I-430 SB to Highway 10 WB and then wanting to turn left on Rodney Parham.

I-30/I-430 Interchange Study



- Location: I-30/I-430 Interchange in Little Rock
- Date: May 3-4, 2011; May 26, 2011; March 13, 2012
- Requested by: Statewide Planning
- How Mast Camera was Utilized:
 - Accurately model the traffic patterns occurring in this interchange area.
 - The camera footage was used in place of attempting volume count data collection on the multi-lane freeway.

- Specifically, the origins and destinations within the weave on I-30 WB between I-430 SB and the Otter Creek off-ramp needed to be viewed.

Interstate Platooning Study



- Location: I-40 near Lonoke, I-40 near Atkins and I-30 near Malvern
- Date: March 25, 2011; May 23, 2011; June 14, 2011
- Requested by: Policy Analysis
- How Mast Camera was Utilized:
 - View the platooning characteristics on rural freeways with high truck percentages.
 - When determining Level of Service (LOS) with Highway Capacity Manual (HCM), everything looked fine, but that is not how it seems to drivers.
 - Lane density was counted for $\frac{1}{4}$ mile distance at any given time.

I-630/Shackleford Intersection



- Location: Intersection of Shackleford and Financial Center Parkway/I-630 in Little Rock
- Date: August 8, 2011
- Requested by: Maintenance Division
- How Mast Camera was Utilized:
 - During the start of lane exchanges on I-630 that lead into the signal at Shackleford & Financial Center.
 - Extremely long queues on I-630 and as with most signals in Little Rock, this signal is connected by radio to a centralized traffic controller server.

- The server synchronizes the traffic signals along the corridor to maximize LOS.
 - The lane changes had upset the previous coordination plans for the corridor, especially at this intersection.
 - The mast camera provided a corridor view of the I-630 approach to this signal.
- This allowed for better development of the coordination plans for this signal and in-turn the Chenal corridor.
 - When we are working on coordination plans it is always better to have video.
 - It allows for direct observation of queues, gaps, offset issues, arrival times, and demand.
 - We can also generate quick counts from video.
 - Having video throughout the day allows for the creation of properly sized coordination plans and when they should be implemented.
 - It can also show that at particular times the signals should not be coordinated at all and instead be run in Free mode.

Study of Adding a New Access Point at an Intersection



- Location: Intersection of Highway 5 (Col. Glenn) and Highway 70B (University Ave.) in Little Rock
- Date: October 4, 2011
- Requested by: Statewide Planning
- How Mast Camera was Utilized:
 - Video was used as a calibration tool in the composition of a microsimulation model to study the effects of a new access point on an adjacent signal.
 - In particular, the camera was used to monitor lane selection and queue lengths.

Highway 71B Interchange Improvements



- Location: Intersection on the East side of I-540 Exit 85
- Date: October 6-7, 2011
- Requested by: Statewide Planning
- How Mast Camera was Utilized:
 - The camera was used to accurately model the traffic patterns occurring in this interchange area.
 - Due to heavy congestion in the area, video of the intersections close to the interchange is good supplemental data for helping determine demand at the intersections instead of just turning movement counts and volume counts.

I-540/Hwy 16/Hwy 112 Spur Interchange Improvements



- Location: Intersections on either side of I-540 Exit 62
- Date: April 10-11, 2011
- Requested by: Statewide Planning
- How Mast Camera was Utilized:
 - The camera was used to accurately model the traffic patterns occurring in this interchange area.
 - Due to heavy congestion in the area, video of the intersections close to the interchange is good supplemental data for helping

determine demand at the intersections instead of just turning movement counts and volume counts.

I-540/Hwy 62 Interchange Improvements



- Location: Intersections on either side of I-540 Exit 64
- Date: April 10-11, 2011
- Requested by: Statewide Planning
- How Mast Camera was Utilized:
 - Used to accurately model the traffic patterns occurring in this interchange area.

- The camera elevation gave us perspective to view traffic movements that would not be picked up on a typical turning movement count or volume count.
- Specifically, needed to see how many vehicles were coming southbound on Shiloh Drive, turning left onto Highway 62/180, and then turning left again onto Futrall Drive.