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Aerial Traffic

Final Report

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Technology
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Infrastructure

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EXECUTIVE SUMMARY

This report documents a significant advancement in work-zone safety through the strategic integration of aerial drone technology and machine vision software. It summarizes the project's phases: Technical Assessment and Procurement, System Integration and Validation, and Deployment Assessment.

The Technical Assessment and Procurement phase led to the selection of Smartek ITS's DataFromSky product for its unique real-time processing capabilities of aerial drone video, making it superior to other commercial offerings.

The System Integration and Validation phase ensured that the video streams, whether real-time or recorded, were processed effectively for varying roadway scenarios, including work zones and intersection monitoring. Accompanying development work included a user-defined data interface with the capability to trigger intruding vehicle alarms.

The Deployment Assessment phase confirmed the system's precision, with object detection up to 150 meters and sub-500 millisecond latency in relaying data for real-time alerts. Despite some GPS data discrepancies due to wind-induced drone movements, the system showed promise in controlled and real-world environments.

Overall, the project acquired and validated the system's functionality, with successful tests on live and recorded video feeds, software video processing, and real-time data transmission, culminating in the development of a robust intruding vehicle alarm mechanism. The system demonstrated great potential for deployment across various Virginia Tech Transportation Institute research initiatives, setting a precedent for future work in enhancing work zone safety.

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API	application programming interface
BSM	Basic Safety Message
HDMI	High-Definition Multimedia Interface
RTSP	Real-Time Streaming Protocol
UDP	User Datagram Protocol
VTTI	Virginia Tech Transportation Institute

CHAPTER 1. INTRODUCTION

Work-zone intrusions are an ongoing area of research and development, as they pose a significant risk to workers and overall work-zone safety. Aerial drone-sourced video and machine vision software advancements provide an excellent opportunity to explore applications that could identify intrusion threats with enough time to warn workers. This project examined the feasibility of using off-the-shelf machine vision systems, leveraging both a tethered aerial drone and pole-sourced video points of view, to assess vehicle trajectories and generate intrusion warning alerts in active work zones. Further, this report describes the integration of intrusion triggers into the Smart Work Zone system to provide alerts to workers via worn equipment, such as hard hats or work vests, or through auditory alarms.

This report is organized based on the following project phases:

- The *Technical Assessment and Procurement* phase focused on identifying and evaluating commercially available solutions capable of processing live video from tethered drones for use in work zone projects. The procurement process resulted in acquiring the most suitable commercial off-the-shelf solution that met our criteria for integration.

- The *System Integration and Validation* phase ensured the entire system's functionality, from the tethered drone and its video feed to software processing and data interfacing. We developed a data interface to integrate the commercial solution into existing Virginia Tech Transportation Institute (VTTI) work zone systems, leading to the creation of a mechanism for providing intruding vehicle alarms triggered by the commercial solution's data.

- The *Deployment Assessment* phase executed test cases for the system in controlled test track scenarios and real-world work zones. By deploying the system's functionality in these environments, we were able to validate performance for potential use in selected test cases.

The outcomes of these tasks were substantial: the procurement of a best-fit commercial solution, a validated vendor system, a newly developed data interface, and a functional intruding vehicle alarm mechanism. Additionally, assessment was performed for test cases on a controlled test track. This effort is reflected in this report, which summarizes all work activities, system assessment results, and recommendations for future work to enhance work zone safety.

CHAPTER 2. TECHNICAL ASSESSMENT AND PROCUREMENT

Initially the team performed a technical evaluation on existing commercially available offerings. This effort focused on identifying a solution that is capable of processing live video from a tethered aerial drone to detect, track, and provide data on vehicles in real time to alert roadway workers of vehicles that may pose a safety risk. Table 1 identifies the capabilities and offerings of each vendor system. Our assessment of the systems' capabilities involved evaluation of vendor website materials, vendor meetings, and direct communications with the company's technical team members.

Table 1. Vendor capabilities assessment.

Vendor	Tethered Drone Hardware	Video Processing Hardware	Video Processing Software	Real-Time Vehicle Application Programming Interface (API) Data	Technical Support
Smartek ITS	X	X	X	X	X
Elistar	X	X	X		
Autelrobotics	X	X	X		
Hoverfly Technologies	X	X	X		
Fotokite	X	X	X		
Yuneec Holding	X	X	X		
DroneUp	X	X			

Based on this evaluation, Smartek ITS's DataFromSky product offers the only known combined commercial off-the-shelf hardware and software solution that can process live video from a tethered aerial drone and output real-time, vehicle object kinematic data in an API. This was the primary criterion and necessary to develop an algorithm to actuate warnings for a work zone (Figure 1). The team was able to evaluate Smartek ITS's software, APIs, code examples, documentation, and technical support with real-world VTTI-collected aerial drone video. This provided confidence in the quality of the vendor solution and its ability to address use cases for our work-zone safety research program. No other vendor was able to provide a live software solution demonstrating the ability to process our video data.

DATA FROM SKY

General properties	
Power supply and consumption	100-230V AC, 11 A@100 V or 5.5 A@240 V, nominal consumption 450W
Weight	16kg
Dimensions	538 × 406 × 269mm
Case	Pelican iM2620 Storm case, injection molded resin
Access	2× press&pull latch
Transportation	soft-grip handle, trolley handle, wheel system
Display options	15,6” wired touchscreen, 12” wireless rugged tablet (optional), external monitor via HDMI (2x, optional)

Video analytics	
Analytic engine	DataFromSky FLOW: 7 detection categories, exact target traces, georegistration, stabilization, detection masks, dynamic and static anonymization
Signal source	HDMI, SDI, RTSP (H.264/H.265), file streamer
Recommended resolution	1080p30
Processing power	>20fps @ 1080p30

Environmental conditions	
Operating temperature	5°C to 40°C
Storage temperature	-20°C to 45°C
Relative humidity	15% to 90% non-condensing (30%/hr max gradient)
Shock resistance – operation	10G (half-sine shock pulses of 2 ms)
Shock resistance – storage	50G (non-repetitive half-sine shock pulse of 2 ms)

Interfaces	
Data Interfaces	REST API, UDP API, Webhooks, MJPEG, Xprotect (VMS-Milestone), GPIO pins (optional)
Inputs	1× Power terminal powerCON Neutrik NAC3MPA 1× HDMI 2.0a 1× SDI 10-bit SD/HD/Ultra HD (BNC)
Outputs	1× RJ45 etherCON Neutrik NE8FDY-C6-B 2× HDMI; maximum resolution 7680x4320@60Hz 2× USB-A 3.0 2× USB-C 3.1 gen 1 1× USB-C 3.1 gen 2 Thunderbolt 3 cable
Wireless	1x WiFi adapter - IEEE 802.11b/g/n 2.4 GHz, IEEE 802.11a/n/ac 5 GHz

Figure 1. Photo. Smartek ITS DataFromSky specification sheet.

The Smartek ITS DataFromSky solution is a computer vision/deep learning–based system for traffic monitoring and data collection. The FLOW software available on their machine can collect video streams from either real-time sources or prerecorded video, process the video through object detection algorithms, and collect metrics based on user-defined parameters as shown in Figure 2. The Traffic Drone unit, along with FLOW, can take video input from Real-Time Streaming Protocol (RTSP), High-Definition Multimedia Interface (HDMI), or prerecorded video files, and output metrics through User Datagram Protocol (UDP) sockets defined by the user through the FLOW user interface. FLOW also has geolocation functionality to provide approximate GPS locations for detected objects based on their relative position to known locations in the frame. The FLOW software allows for different configurations for real-time and post-processing use cases. The user can define the trajectory smoothing interval, payload request interval, and computation tick interval.

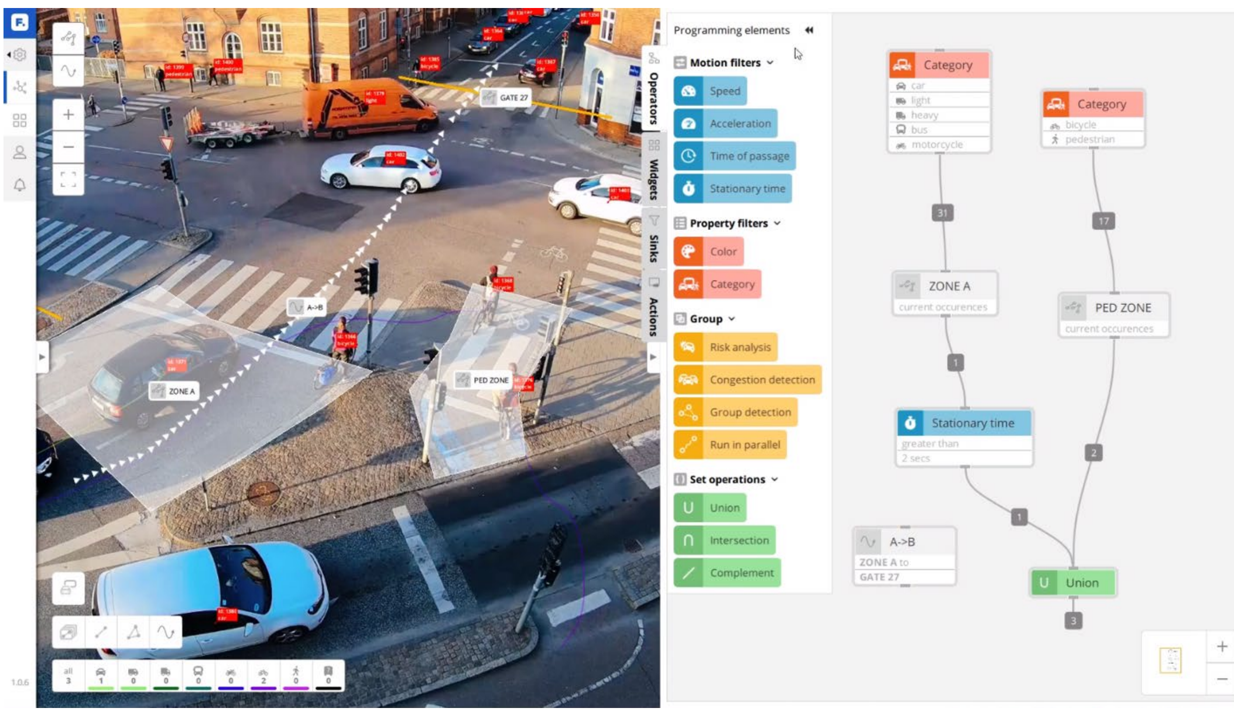

Figure 2. Diagram. Smartek FLOW software.

CHAPTER 3. SYSTEM INTEGRATION AND VALIDATION

The Traffic Drone Unit is a versatile system that can address a wide variety of roadway uses, ranging from work zones to intersection monitoring. Further the system can process video streams in real time, as well as recorded video to support post-analysis activities. As part of initial system integration and validation efforts, the team leveraged existing prerecorded video to aid in software development before deploying in real-world, real-time data processing situations.

The FLOW software runs on the Drone Unit hardware. The software offers an interface that allows the user to define data areas of interest and the method of data acquisition. Options include zones of interest, certain vehicle types in a range of speeds, over a defined time interval, etc., as illustrated in Figure 3. The system allows users to define sinks to send the data through a user-defined channel. For the assessment, we used the UDP object list sink to receive a list of objects that had been detected.

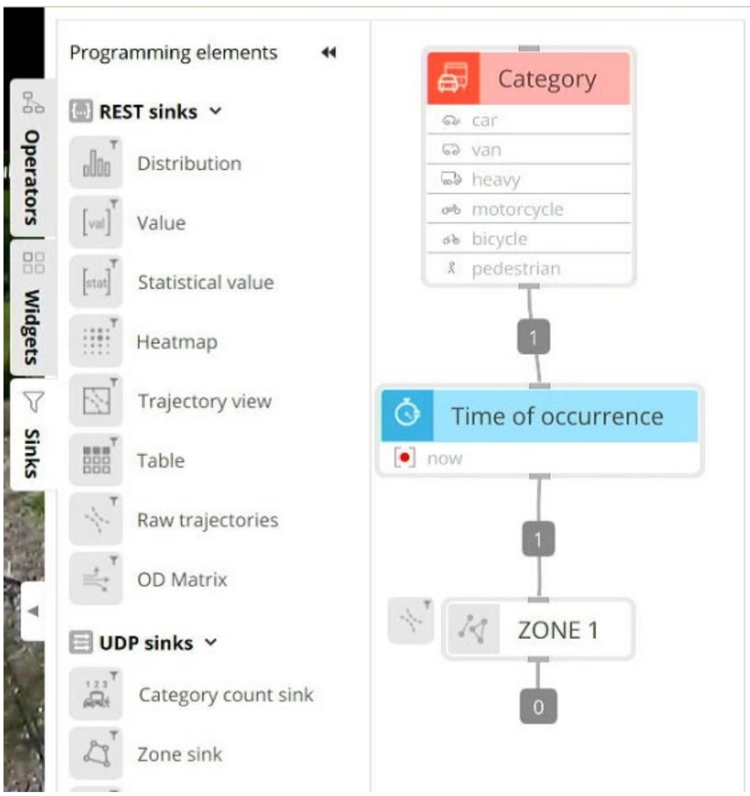

Figure 3. Screen capture. FLOW software data of interest selection.

Prerecorded drone footage was used as part of the software development process. Specifically, a DJI Inspire drone collected top-down video of vehicle paths through the intersection of Peppers Ferry Road and North Franklin Street in Christiansburg, Virginia. As shown in Figure 4, the FLOW software can import existing drone video footage and overlay data areas of interest—in this example intersection inflow and outflows—while also tracking vehicle trajectories. Further, the FLOW software allows available data elements to be selected and transmitted to an external device.

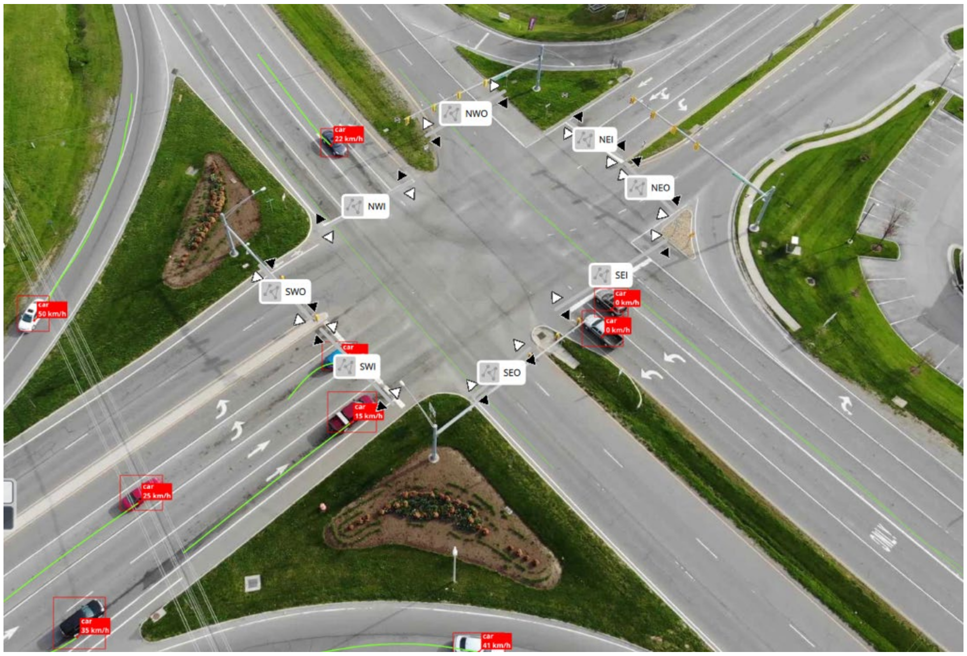

Figure 4. Vido capture. FLOW software of prerecorded drone footage with traffic inflow and outflow overlays.

Figure 5 illustrates the software development data flow, which is based on the interfaces available from the FLOW software running on the Drone Unit hardware platform. Initially, prerecorded video was used to simplify the baseline software development process, as opposed to developing on live video via RTSP. As illustrated in the diagram, utilizing the "Pre-Recorded Footage" path, a video MP4 file was loaded into the Drone Unit system. The FLOW software was configured based on the roadway characteristics of the prerecorded video, as well as zones of interest. If a vehicle entered a specific defined zone, UDP messages were generated from the Drone Unit and transmitted to the VTTI developer's Local Machine. The Local Machine processed the incoming data to generate an alert to send to a Smart Vest, while also generating pseudo Basic Safety Messages (BSMs), as illustrated in Figure 6. In addition to the primary use case of work zone alerts, the pseudo BSMs were also transmitted to the Virginia Connected Corridors (VCC) service for data collection and future application development use cases.

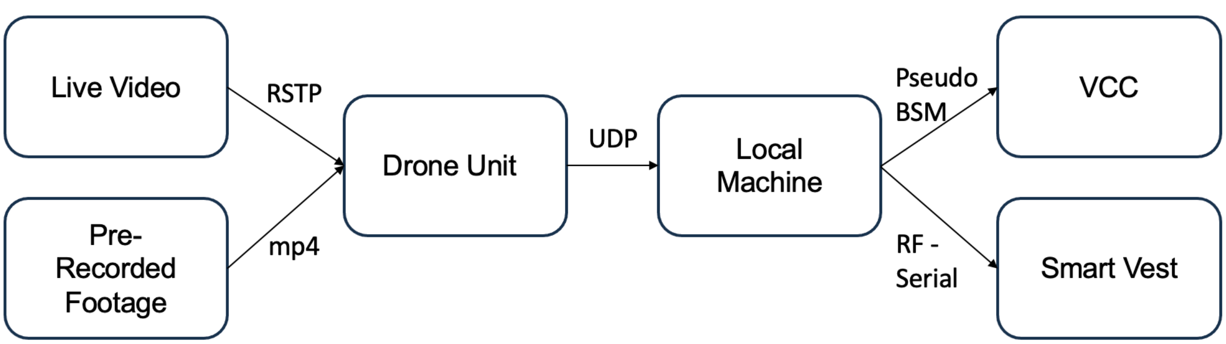

Figure 5. Diagram. DataFromSky software development system data flow.

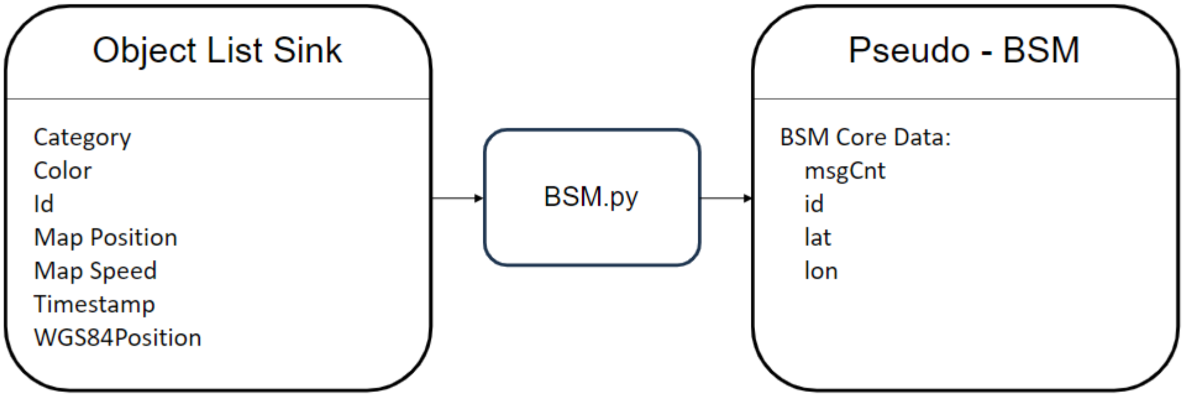

Figure 6. Diagram. Relevant DataFromSky data elements utilized.

To further test the FLOW system, along with the VTTI-developed software, prerecorded video footage was used from Smart Intersection cameras mounted on traffic lights at the US-29 and Nutley intersection in Northern Virginia. The prerecorded video was imported, the FLOW software was configured, and VTTI software processed UDP data to generate BSMs, which were transferred to the VCC service via WebSocket. Figure 7 shows the generated BSM data as displayed in the VCC Monitor application. Having such data flow through the VCC enables future connected work zone applications to be developed utilizing this system.

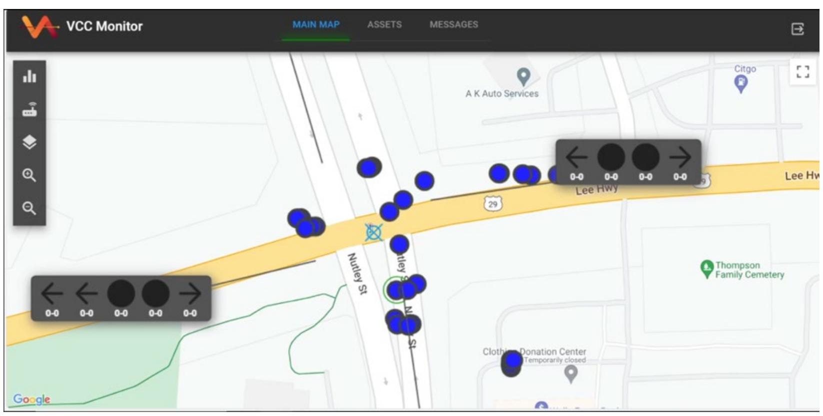

Figure 7. Screen capture. VCC Monitor showing generated DataFromSky pseudo BSMs.

CHAPTER 4. DEPLOYMENT ASSESSMENT

The team tested the functionality of the Traffic Drone Unit to detect vehicles intruding into a work zone and transmit alerts to the Smart Vest on the VTTI Smart Roads Highway. For work zone monitoring, the team utilized both drone (Figure 8) and telescoping pole mount (Figure 9) HDMI cameras in real time to monitor if a vehicle intruded into a user-defined zone. A DJI Inspire drone and a telescoping pole mount equipped with a MOKOSE HDC10-3.2MM camera pointed at the work zone were utilized. The video was processed in 1920 by 1080p with real time configuration.

Figure 8. Photo. Drone video view of work zone.

Figure 9. Photo. Telescoping pole-mounted camera view of work zone.

From the assessment, the team was able to verify that the system was able to detect and identify objects at up to 150 meters with both drone and pole-mounted views. The system exhibited an efficient object detection latency, with the transmission from the Drone Unit to the Local Machine via UDP protocol being typically less than 500 milliseconds. This swift response allowed the system to deliver real-time warnings to a Smart Vest, enhancing safety measures. However, it was observed that the Detection Zones, defined in pixel space, experienced shifts when the aerial drone was in use, attributable to drift from wind conditions. This variability occasionally affected the accuracy of GPS-derived location and speed data, indicating an area for further refinement. A means to geo-stabilize the mapping of pixel space to ground landmarks could be developed and applied to the data in real time to eliminate or reduce the error observed due to drone drift.

CHAPTER 5. PROJECT OUTCOMES

Based on the efforts described in this report, the team was able to successfully acquire, integrate and verify end-to-end commercial system functionality for an aerial drone-based system to improve work zone safety. This effort entailed testing the drone's video input, both live and recorded, software video processing, graphical user interface marking, and the UDP object data interface. Moreover, a new data interface was developed to seamlessly integrate the commercial system with the existing VTTI work zone systems for enhanced alarm functionality, as well as with the VCC for industry-standard Representational State Transfer (REST) API-driven data archiving and monitoring. The project was successful in creating reliable intruding vehicle alarms using the object data from the commercial system, proving its versatility and ability to be deployed across a wide range of VTTI research activities and real-world use cases.