

# Connecting Work Zones in Western New York:

Real-Time, Real-Presence Work Zone  
Status for Efficient and Safe Driving

Final Report | Report Number 22-06 | March 2022



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# **Connecting Work Zones in Western New York: Real-Time, Real-Presence Work Zone Status for Efficient and Safe Driving**

*Final Report*

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# Abstract

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# Keywords

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work zone data, connected technology, connected vehicle, arrow board, flagging

# Acknowledgments

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## Acronyms and Abbreviations

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FHWA	Federal Highway Authority
IoT	Internet of things
NITTEC	Niagara International Transportation Technology Coalition
DOT	New York State Department of Transportation
NYSTA	New York State Thruway Authority
TMA	Truck Mounted Attenuator
U.S. DOT	United States Department of Transportation



# Executive Summary

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The development and sharing of data regarding the location and status of surface transportation work zones are two of the top priorities for state and federal transportation stakeholders, due to its potential impacts on safety and efficiency of the transportation system.

iCone Products LLC (IPL), a New York State based company, develops connected technologies for work zone traffic control equipment. IPL offers tools that allow contractors and agencies to upgrade their existing fleets of traffic control equipment with real-time connectivity. It also provides electronically marked roadwork activities that can be integrated with other traffic management and individual vehicle navigation systems. This data can provide a regional mobility management system with real-time information that can potentially bring road maintenance, safety, and trip optimization benefits.

The goal of the project was to demonstrate underutilized connected work zone technologies across critical routes in New York State's Niagara region. The project provided innovative work zone connective technology to the public agencies that participate in the Niagara International Transportation Technology Coalition (NITTEC). A total of 91 pieces of equipment were delivered across the region. Three years into the project, approximately 10 of those units were in daily use by various New York State agencies. The project also evaluated equipment performance, data, and user adoption across the region. Contractors and agencies in other parts of the State have since adopted similar IPL technologies, making New York State one of the top 10 states for the generation of real-time work zone data.

# 1 Background

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In 2015 iCone Products LLC (IPL) began to engage with the automotive industry in order to preemptively address concerns that the highway construction industry was expressing regarding the introduction of automated vehicles. A key takeaway from these discussions was an industry prioritization on generating and organizing data about the location and status of construction and maintenance work zones. In 2018 the Federal Highway Authority (FHWA) launched the Work Zone Data Working Group (WZDWG) and the Work Zone Data Exchange (WZDX), making the generation and dissemination of data on work zones a key priority for the United States Department of Transportation (U.S. DOT). IPL was one of the first members of these groups.

From 2015 onward, IPL introduced a series of products based on an Internet of Things (IoT) structure. These products allow for the monitoring of the location and status of the equipment that is used for the temporary traffic control of work zones. These products made up the ConnectedTech™ product line for iCone Products.

In 2018 when this project commenced, states such as Nevada, Virginia, and Colorado had begun to experiment with the ConnectedTech™ tools as a means of automatically generating data on the location of active work zones. At that time there was no connected work zone technology in New York State. This project was established to give the several agencies that operate in the Niagara International Transportation Technology Coalition (NITTEC) region an exposure to the ConnectedTech™ product suite and to determine the efficacy of the tools.

As the project progressed, based on further industry feedback, other tools and features were added to the ConnectedTech™ family of products. When these new tools became available, they became candidates for inclusion in this project and in some cases replaced the tools that were originally considered by the participants.

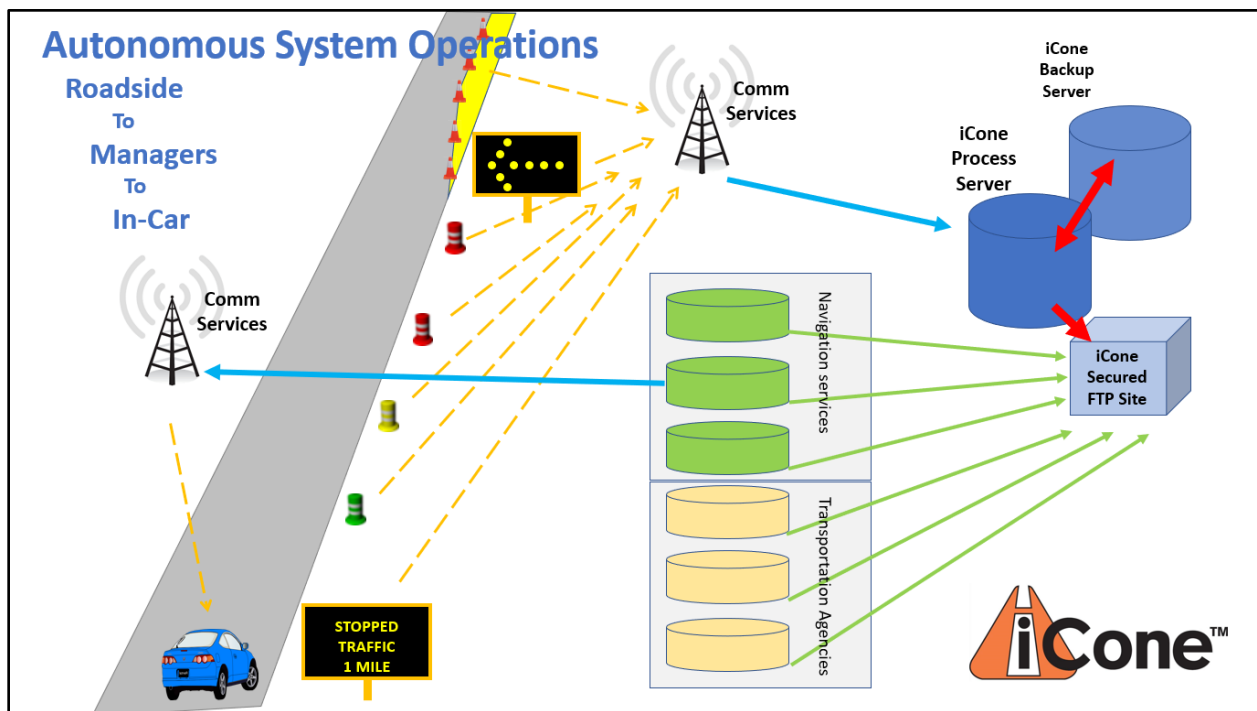
## 1.1 Description of Equipment

iCone ConnectedTech™ tools are autonomous, or near-autonomous monitors for the equipment commonly used in temporary traffic control. These tools operate in an IoT framework regularly monitoring the status of their host equipment and contacting central servers at regular intervals or

when the status of the equipment changes. The diagram of the system in Figure 1 shows how multiple types of equipment independently interact with the servers to get their piece of the work zone picture to traffic centers and drivers.

These autonomous tools are mounted on equipment such as arrow boards, portable signals, or hazard lights. Tools that are nearly autonomous, such as the iPin or the Flagging Baton, generally only require that the worker turn the device on or off at the beginning/end of the task. A more detailed description of the tools that were available to the project participants follows. Detailed data sheets can be found in appendix B.

**Figure 1. iCone ConnectedTech™ System Operation**



### 1.1.1 iCone V3.0—iBarrel

The iCone V3.0 is a largely autonomous traffic sensor that uses a doppler radar to monitor the speed of passing traffic. It is self-contained in a standard traffic barrel that is compliant with Manual on Uniform Traffic Control Devices (MUTCD) in appearance and National Cooperative Highway Research Program (NCHRP) Cat 2 crash certification.

### **1.1.1.1 Queue Warning Trailer**

The Queue Warning Trailer is a Portable Changeable Message Sign (PCMS) equipped with a cellular modem built to carry four iCones and programmed to easily set up basic queue warning.

### **1.1.2 Workers Present Beacon—iPin**

The Workers Present Beacon was originally a ConnectedTech™ beacon built into a Type B work zone light. The intention was to give workers a device that could broadcast the location of road work when activated. In late 2018 at the request of the Colorado Department of Transportation, the same function was recast as a rod that could be dropped into the top of a traffic cone and became known as the iPin™. The market acceptance of the iPin™ was greater than the Type B light, which was removed from the product line.

### **1.1.3 Flagging Baton**

The Flagging Baton is a patented application of the ConnectedTech™ circuitry in the pole of a STOP/SLOW paddle. When the worker turns on the Flagging Baton it locates the worker and notifies the database that flagging operations are active at that location.

### **1.1.4 Work Zone Connectivity Box—Arrow Board Kit™**

The Work Zone Connectivity Box has a foundation in the ConnectedTech™ circuitry as an aftermarket kit which is used to monitor the status of existing traffic control equipment such as portable signals, arrow boards, or truck hazard lights to name a few. For the purposes of this project the arrow board kit was used to monitor the location of the arrow board and the arrow pattern that is displayed.

### **1.1.5 Work Zone Connectivity Box—Hazard Light Kit**

The Work Zone Connectivity Box has also been built out in a version which allows agencies to monitor the status of the hazard lights on work trucks and other vehicles. Prior to stopping to work on the road, a worker will turn on a truck's hazard lights to warn approaching drivers of the activity, signaling drivers to be more careful thereby preventing possible accidents. The ConnectedTech™ Hazard Light Kit is wired into the power system of the vehicle's hazard lights so that when the worker turns on the hazard lights to visually warn oncoming drivers the Hazard Light Kit transmits a message which appears in vehicle navigation systems as a caution for a "work truck ahead."

## 2 Training and Distribution of Equipment

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### 2.1 Training

When systems that are intended to monitor work activity are properly designed, the system itself requires little or no crew training to operate. For infrastructure owners, one of the challenges in adopting connected work zone technology tends to be adjusting the agency’s concept of operations to place an organizational emphasis on specific tools and the leveraging of the data that those tools generate. As a result, introducing an agency to connected work zone concepts must focus on determining which traffic control activities are a priority for the agency’s operations and the traveling public.

For this project, training sessions centered on three subjects: (1) familiarity with equipment options, (2) data access and uses, and (3) the explanation and demonstration of using the equipment in the field. iCone and NITTEC held five training sessions for the member agencies in which each of the connected work zone monitoring tools was discussed. The locations for the training sessions included the conference rooms of NITTEC and the New York State Thruway Authority (NYSTA) regional offices as well as two of the field offices of the Erie County Highway Department.

Generally, the individuals that attended the training sessions in the NITTEC and NYSTA facilities were traffic engineering professionals and people with responsibilities in traffic centers. Erie County was able to involve several members of their maintenance crews by hosting training sessions in their field offices.

**Table 1. On-Site Training Sessions**

Training Date	Attendees
<b>Q3 2017</b>	Erie County
<b>Q4 2017</b>	Erie County and NITTEC
<b>Q2 2018</b>	Erie County, Niagara County, City of Buffalo, NYSDOT, NYSTA, NITTEC
<b>Q4 2018</b>	Erie County
<b>Q3 2019</b>	NITTEC, NYSDOT, NYSTA, Erie County

The engineers at several member agencies quickly saw value in the iCone (iBarrel) speed sensor and the ability to monitor traffic and potentially execute queue warning and other traditional smart work zone strategies. Each of the agencies requested the iCone V3.0 after the first training session.

The newer tools to monitor workers' presence, flagging operations, and lane closures were not as obvious to the agencies at first. However, in the first quarter of 2018 the participating agencies requested a selection of iPins, flagging batons, and arrow board kits.

## 2.2 Distribution of Equipment

Delivery of equipment began in the fourth quarter of 2017 and continued into 2019 as supply issues and demand pressures resulted in minor delays. While the larger pieces of equipment were delivered to the various maintenance facilities, most equipment was delivered to NITTEC, which took responsibility for further distribution to the participating agencies. A total of 95 pieces of equipment were provided to the program.

Later in 2019 there were several pieces of equipment that were not utilized, and requests had been made by the headquarters of the NYSTA and the NYSDOT Region 3 for equipment loans. In total six arrow board kits and four flagging batons were loaned to these agencies.

**Table 2. Final Allocation of Equipment by Type**

<b>Name</b>	<b>iCone V3.0 (iBarrel)</b>	<b>Arrow Board Kit</b>	<b>iPin/Workers Present Light</b>	<b>Flagging Baton</b>	<b>Queue Warning Trailer</b>
<b>City of Buffalo</b>	4		1		
<b>Erie County</b>	8	4	20	8	
<b>Niagara County</b>					
<b>NITTEC</b>			10	13	1
<b>NYSDOT R5</b>		1	6	1	
<b>NYSTA</b>	4	5	2		
<b>NYSDOT R3 (on loan)</b>		1		4	

## 3 Data Streaming

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### 3.1 iCone Streaming Service

As a standard of practice, iCone Products provide the data that is generated by the ConnectedTech™ product line to the owners of the equipment and the agencies of the regions in which the equipment is activated. The common data streaming process is through a File Transfer Protocol (FTP) file exchange in which either “assets” feed or a traffic “incidents” feed in XML or JSON format.

There are two basic categories of feeds that are available. First there is an “asset” feed which includes the coordinates of the equipment’s location and status regardless of whether or not the equipment is actively operating for a traffic control purpose. The asset feed is generally intended so that the owners of the equipment can manage their assets whether that equipment is in use or not. A piece of equipment, such as a portable traffic signal, is tracked and monitored regardless of whether or not it is functioning in a traffic control manner. The location and status of that equipment shows up in the “asset” feed as long as it is in the owner’s inventory.

The second, and more common, category of feed is an “incident” feed where the location and status of the equipment is given only when the equipment was in use performing a traffic control function. The incident feed is generally intended so that the owners of the equipment can manage their assets when the equipment is in active use and its activity is related to a specific event. For instance, an arrow board that is displaying a left arrow is denoting an incident that is a right lane closure. When the arrow board is turned off it implies that the incident, the lane closure, is over and the item disappears from the feed.

While iCone Products has willingly built custom formatted feeds for a variety of agencies, the default feed for traffic incidents was based upon the format of the Waze incident feed. The Waze incident feed is a relatively simple structure which most traffic centers actively provide and absorb from the Waze organization. The stream basically allows the exchange of a variety of events such as “construction,” “hazard,” or “road closure.” The standard “incident” feed that iCone Products provides extends the Waze format to include additional information such as “Construction, Lane is Closed, Merge Left.”

An example of iCone Products’ extended incident feed is included in appendix A.

## **3.2 Niagara International Transportation Technology Coalition and Department of Transportation Data Reception**

Temporary traffic control tools, such as arrow boards, that are enabled with connected technologies are not generally deployed by the maintenance crews with any sort of advanced knowledge by the agency's information technology (IT) staff. In general, the IT staff of most agencies have no interaction at all with the maintenance crews. In fact, the lack of contact between field staff and IT staff is the exact reason that it is desirable to upfit the traffic control equipment with IoT technology to report where equipment is being deployed.

The iCone ConnectedTech™ system continuously collects data on the status and location of thousands of pieces of temporary traffic control equipment. This data is grouped by region or ownership and compiled into files which are made available on password protected servers so that participating agencies can download the same files, read the equipment status, and utilize it for traffic and project management purposes.

Throughout the term of the project, iCone posted the incident files for all of the ConnectedTech™ equipment in the State of New York on a file transfer account. In the first quarter of 2020 Niagara International Transportation Technology Coalition (NITTEC) hosted a meeting with iCone and the NYS 511 group to discuss the technical issues with incorporating this data into the State's traffic data system. During that meeting, NYS 511 stated that they were unable to use the latitude and longitude data, and instead associated equipment location data with an address and for entry in the State's database. It was determined that the software provider, IBI, would require a contract to make the changes necessary to absorb the data.

Without the resources to contract with IBI for software changes, NITTEC and DOT have not been able to collect data from the iCone site and incorporate it into New York State's data systems. Recently, iCone has learned that other states that use iCone equipment have contracted with IBI to write the necessary software to integrate iCone data with traffic centers, including the New York State system.



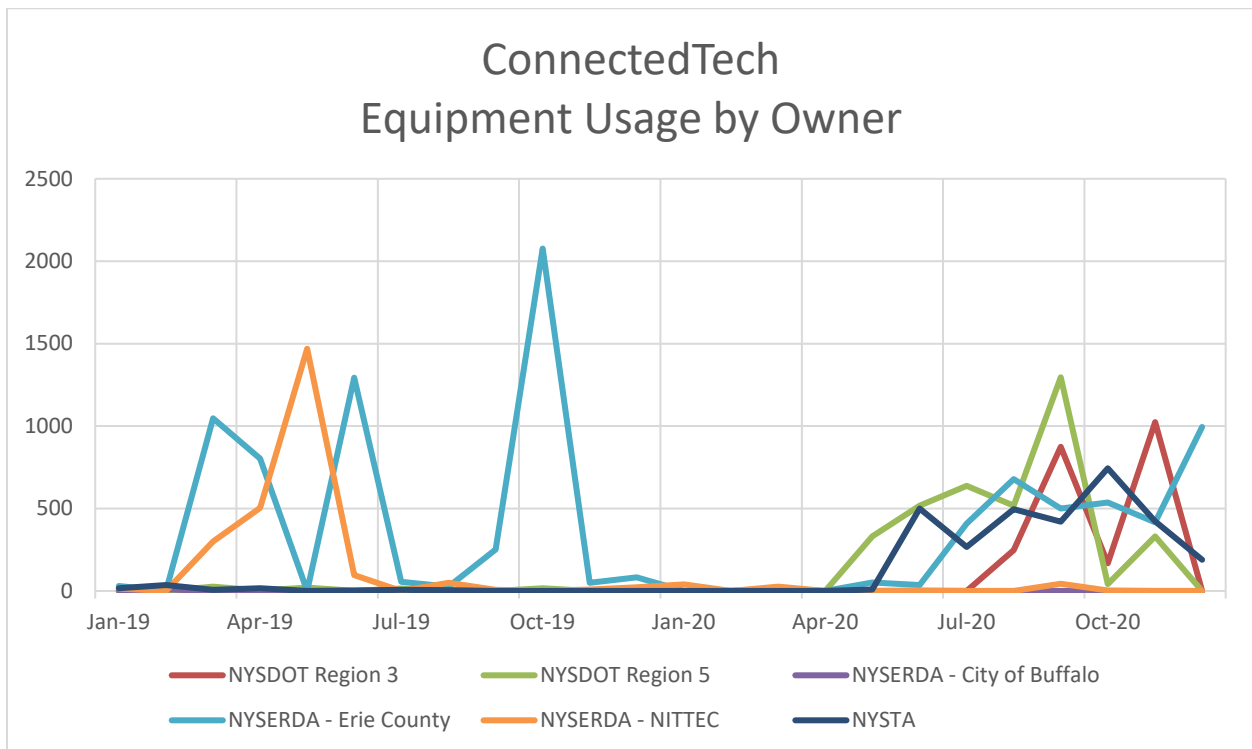
## 4 Analysis of Results

### 4.1 Equipment Utilization

The Niagara International Transportation Technology Coalition (NITTEC) consists of five members on the United States side of the border. These agencies have generally similar duties to build and maintain the road network in Western New York, but they own very different types of roads and have very different priorities. When this project commenced, each of the participating agencies had different needs. As a result, the rate at which each agency stepped up to use the ConnectedTech tools varied.

**Figure 2. Equipment Usage by Owner**

Location reports from ConnectedTech equipment categorized by agency. City of Buffalo equipment is conflated with NITTEC equipment.



The engineers at Erie County and the City of Buffalo had immediate uses for the data that the ConnectedTech™ devices generate, and these entities were quick to utilize the iBarrels and iPins throughout 2018 and 2019. Late in 2019 the Arrow Board Kits were installed in Erie County, DOT, and NYSTA equipment. This particular piece of equipment fits better with the highway operations of the State agencies and once the Covid shutdown was over, the utilization of all of the agencies increased.

Closer to the conclusion of the project, two of the five agencies, Erie County and NYSTA, settled on the ConnectedTech tools they will continue to use into the future. For Erie County the tool of choice is the iBarrel. For the NYSTA the tool of choice is the Arrow Board Kit, which will come pre-installed on newly purchased Truck Mounted Attenuator (TMA) trucks.

## 4.2 Traveler Information

While the auto industry is working on the business structures and technical aspects of providing real-time construction, traffic and weather information, through in-dash systems, relies upon navigation apps such as Waze and Google Maps. It is hard to determine exactly how many drivers use Google Maps on a regular basis, but it is one of the most used navigation tools in the United States with more than 130 million users. Waze actively tracks usage in every country and region, rivaling Apple Maps in second place with around 30 million monthly users. iCone Products actively pushes its data to Waze and Google Maps and is developing relationships with several car companies.

According to Waze the daily usage in the greater Buffalo region has grown from 11,300 to 12,300 users. Google Maps has approximately four times more users than Waze which would imply that roughly 50,000 drivers in the greater Buffalo region use either Waze or Google Maps each day.

In August of 2019, after most of the equipment had been distributed to the NITTEC agencies, iCone reported to Waze and Google 84 unique construction incidents in the greater Buffalo region. By the end of the project the use of iCone’s ConnectedTech product line had been adopted by the NYSTA and several other contractors that operate in the State. As a result of the spread of the technology, in August of 2021 more than 7,600 unique reports were made to navigation apps with an estimated 5,500 positive acknowledgements from Waze drivers.

**Table 3. Growth in Reporting of Work Zone Events 2019 versus 2021**

	<b>Unique Reports to Navigation</b>	<b>Regional Navigation Viewers (Waze and Google Maps)</b>	<b>Minutes of Reporting</b>	<b>Positive Driver Feedback (Waze)</b>	<b>Estimated Driver Alerts (Waze and Google Maps)</b>
<b>August 2019 Buffalo Region</b>	84	50,000			
<b>August 2021 New York State</b>	7,626	2,400,000	367,086	5,500	165,000

The Waze organization does not have a record of how reports of positive driver feedback in the Waze app correlates to the number of drivers that actually viewed the alert but did not provide feedback. At the same time, experienced Waze users and Waze editors generally agree that for every driver that provides positive feedback of an incident alert at least 10 other drivers viewed the alert but did not provide feedback. Therefore, in August 2021 when 5,500 drivers provide positive feedback of a construction alert on Waze, we can infer that more than 50,000 drivers saw those alerts on Waze and likely three times that number saw the same alert on Google Maps.

It is rather difficult to determine just how often the incidents reported to Waze and Google Maps results in the rerouting of traffic. Waze does not have visibility into when each route calculated by its algorithm is altered from the shortest route to an alternate route based upon determining if the alternate route is actually faster due to construction. Google Maps does not return driver activity information from the handset to Google's servers, so they have no feedback on how traffic and incidents affect driver decisions.

Informal user surveys that iCone has administered have resulted in an estimate that between one and three percent of navigated trips have the routes readjusted to account for reported construction or traffic incidents. Based upon the low end of these estimates, it can be inferred that at the conclusion of this project in the second quarter of 2021 nearly two thousand vehicles were likely rerouted around ConnectedTech™ work zones in New York State.

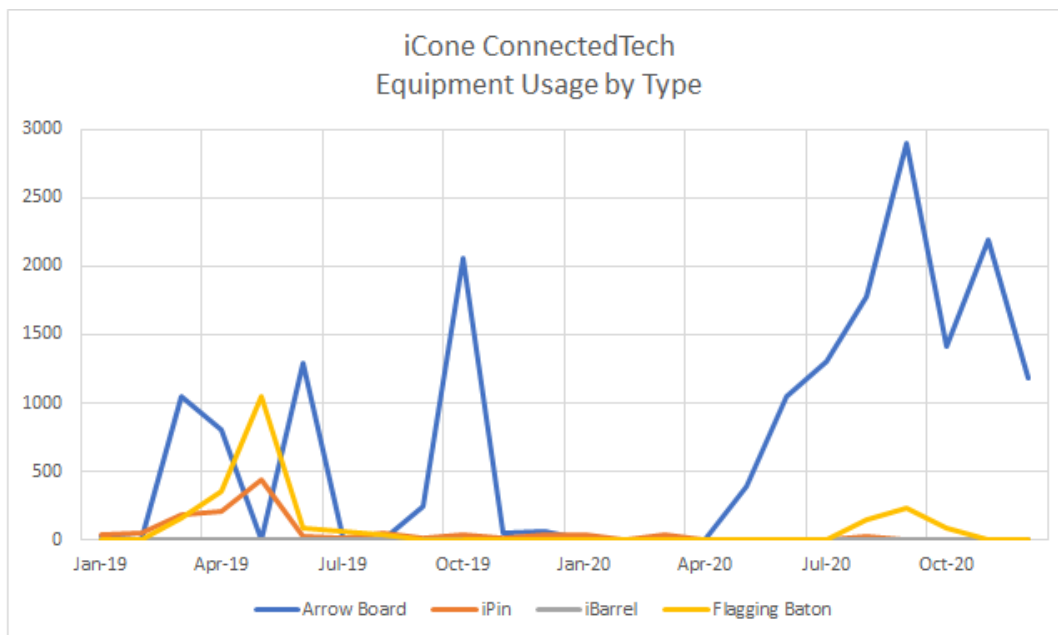
## 5 Observations and Findings

### 5.1 Equipment Utilization

During the term of the project, iCone delivered to the NITTEC member agencies a variety of equipment, some of which operated with complete autonomy, while others required the worker to actively deploy and activate the equipment. The iPin, Flagging Baton, and iBarrel require the worker to perform an extra task. The Arrow Board Kit operates automatically whenever an arrow board is in use. The worker is often unaware that the trailer or truck mounted arrow board has been modified.

**Figure 3. Equipment Usage by Type**

Location reports from ConnectedTech equipment categorized by type.



Early in the project, shortly after the equipment had been delivered, usage by engineering and management staff of participating agencies was rather high and all of the tools were used regularly. The staff of the City of Buffalo and of Erie County built specific plans to incorporate these tools into their management and public information functions. Figure 3 demonstrates the appreciable utilization of all the types of ConnectedTech™ equipment in 2019. The figure also shows the near complete discontinuation of work in the spring of 2020, at the beginning of the Covid Pandemic. Later in 2020 and into 2021 road work resumed and, while the effort to use the iPin and Flagging Batons basically ended, the Arrow Board Kits continued to connect work zones because their operation was fully automated.

In summary, when an agency's management is engaged with the field crews and encouraging the use of the equipment, all types were used regularly. When that engagement lapsed, the organization reverted to previous practices and only the fully automated equipment, in this case, Arrow Board Kits, continued to work providing data and safety benefits. By the end of the third quarter of 2021, the continued implementation of the agency's Arrow Board Kits and the private sector's adoption of this same technology demonstrated that this particular connected work zone technology was one of the fastest ways to launch a data collection effort for work zones.

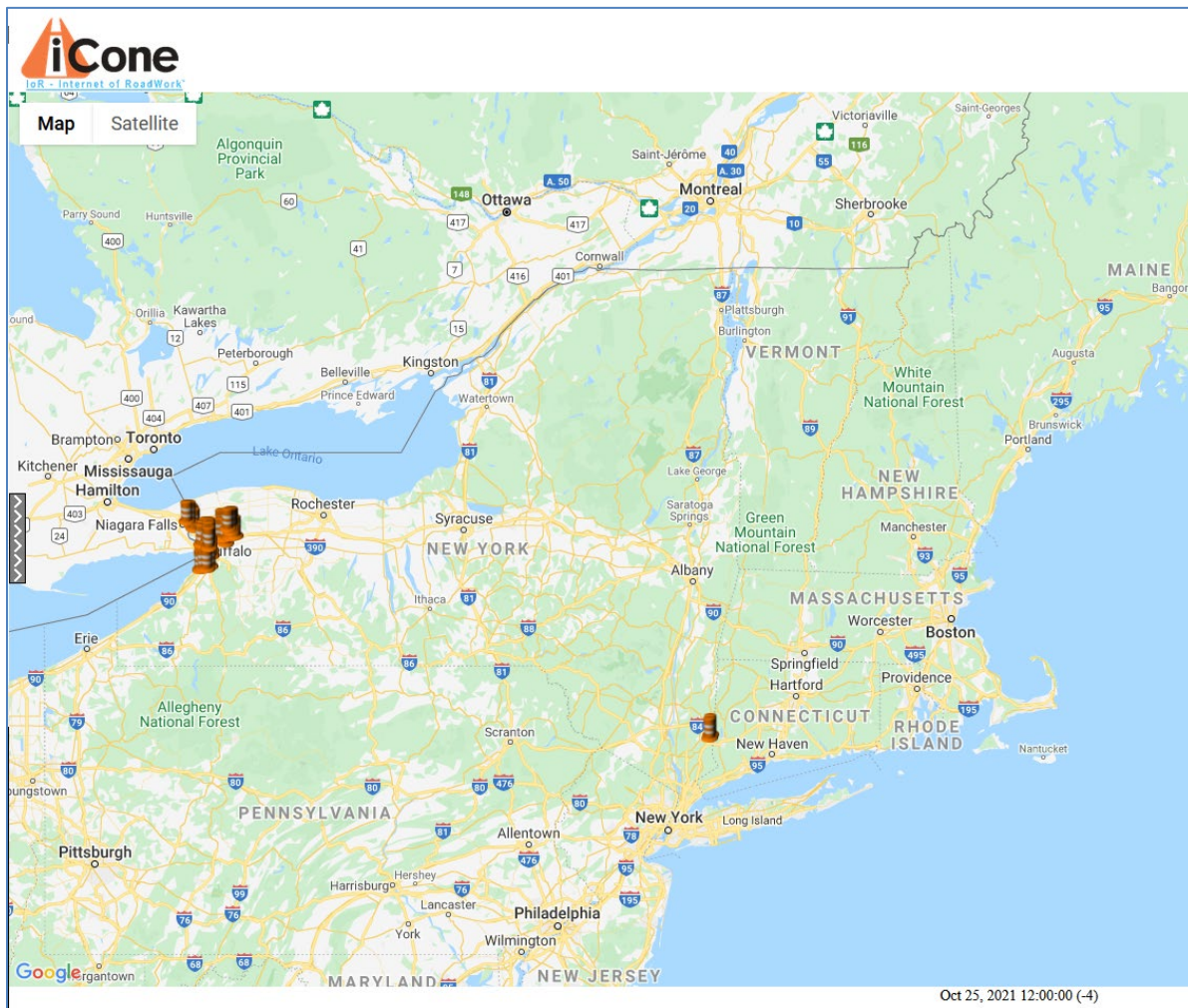
### **5.1.1 iCone V3.0—iBarrel Utilization**

Erie County and the City of Buffalo used the iBarrels extensively to gather speed data in traffic studies including studies at the Buffalo Bills games. As this project concludes iCone has recently been contacted by Erie County with plans to deploy the iBarrels for another traffic survey.

DOT used the iBarrels for a queue warning setup on a bridge project on I-290. This effort ran into some contract issues, so the queue warning system did not go beyond the testing phase. Figure 4 shows the deployments of the Arrow Board Kits procured for the project from 2018 through the third quarter of 2021.

## Figure 4. Regional Usage of iBarrels

Location reports from iBarrels, Quarter 1, 2018 through Quarter 2, 2021.



### 5.1.2 iPin Utilization

The iPin was a replacement for the Workers Present light at road construction sites after the states of Colorado and Iowa requested a work location marker that fit a standard traffic cone without requiring an apparatus to attach the marker. With strong support for this new solution in a number of other states, iCone recommended using the iPin rather than the Workers Present light. The Workers Present light has since been removed from the iCone product line.

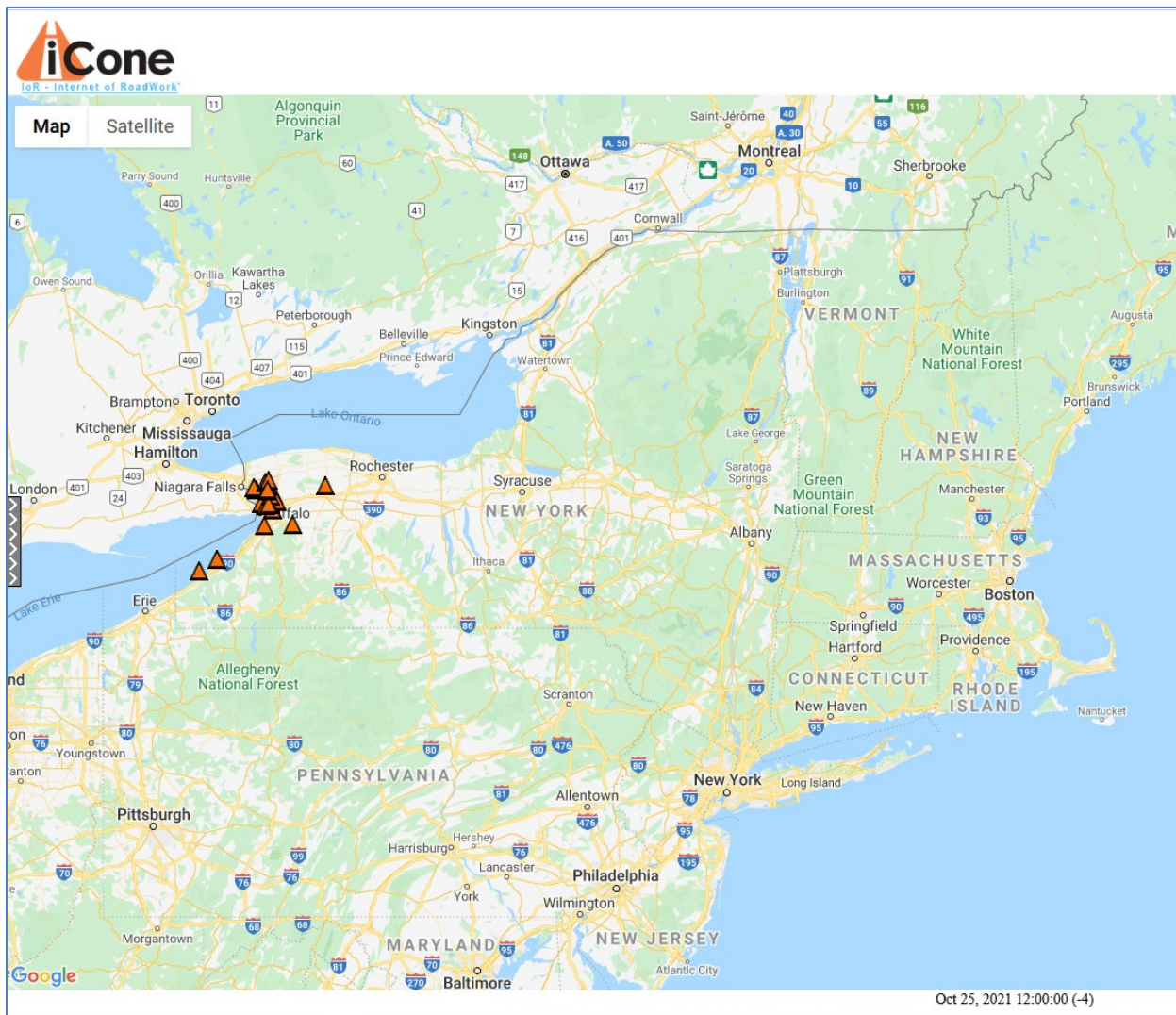
The NITTEC members requested a significant number of iPins. Trials of the iPins were encouraging during the 2019 construction/maintenance season. At the end of the 2019 season both the City of Buffalo and Erie County were developing plans for more extensive utilization, but the 2020 Covid pandemic impacted staff focus from these plans. Figure 5 shows the deployments of the iPins procured for the project from 2018 through the third quarter of 2021.

The City of Buffalo used iPins to mark maintenance work and explored designating specific iPins to mark sidewalk work. Erie County also assigned iPins to specific work crews to mark the location of their work. At the conclusion of the 2019 season the engineers of Erie County were developing work plans to assign iPins to each of the mowing crews, both to warn approaching drivers and to create a record of the progress of these crews.

The NYSTA also assigned iPins to several crews in 2019 and actually assigned several to the Williamsville Fire Department that regularly responded to calls on the Thruway.

**Figure 5. Regional Usage of iPins**

Location reports from iPins, Quarter 1, 2018 through Quarter 2, 2021.



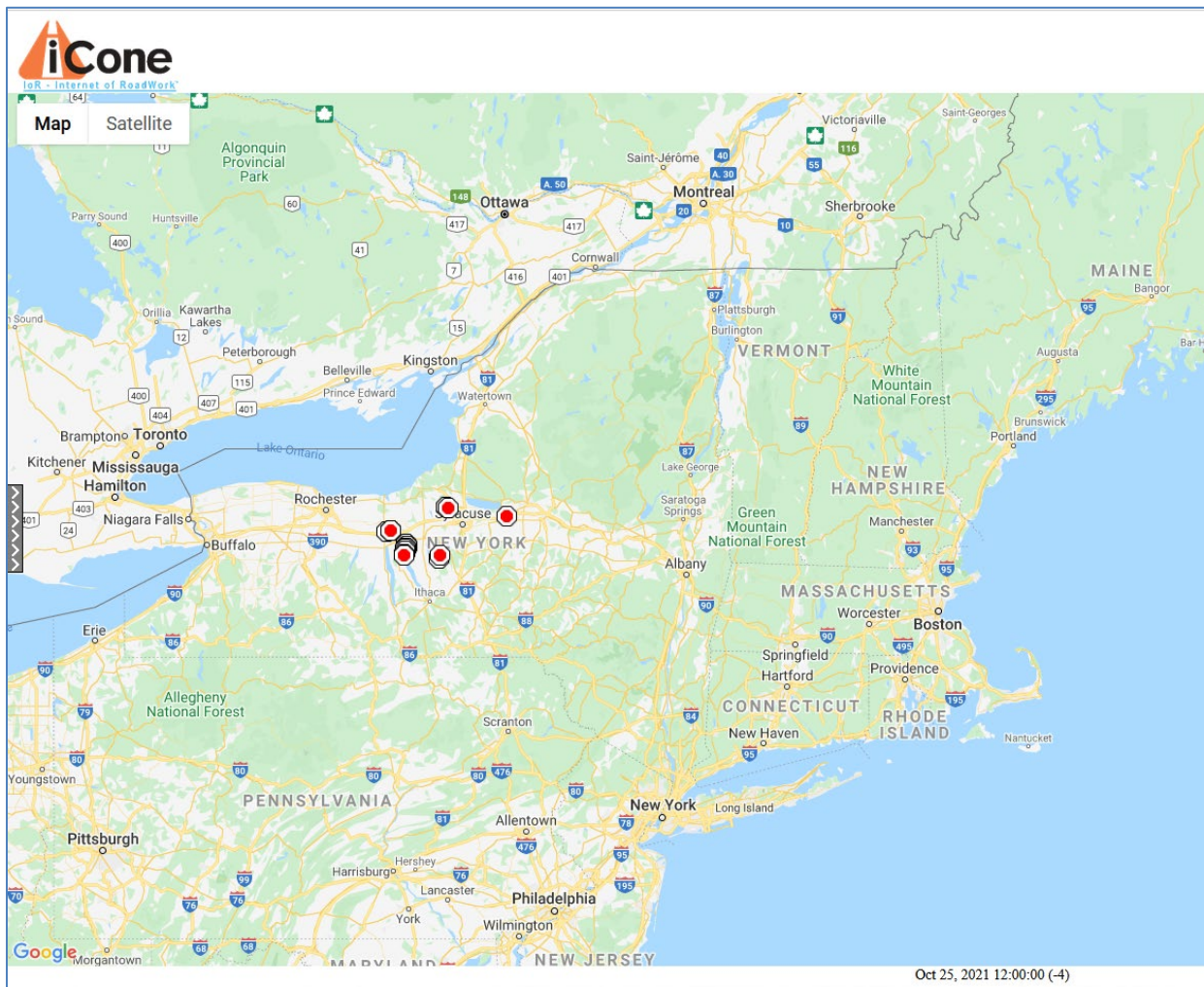
### 5.1.3 Flagging Baton Utilization

While Erie County and DOT Region 5 both requested Flagging Batons during the 2019 season, neither agency actually used them in the field. However, staff in DOT Region 3 expressed significant interest in using this flagging equipment. Several of the Batons were lent to Region 3, providing use throughout 2019. Figure 6 shows the deployments of the Flagging Batons procured for the project from 2018 through the third quarter of 2021.



## Figure 6. Regional Usage of Flagging Batons

Location reports from Flagging Batons, Quarter 1, 2018 through Quarter 2, 2021.



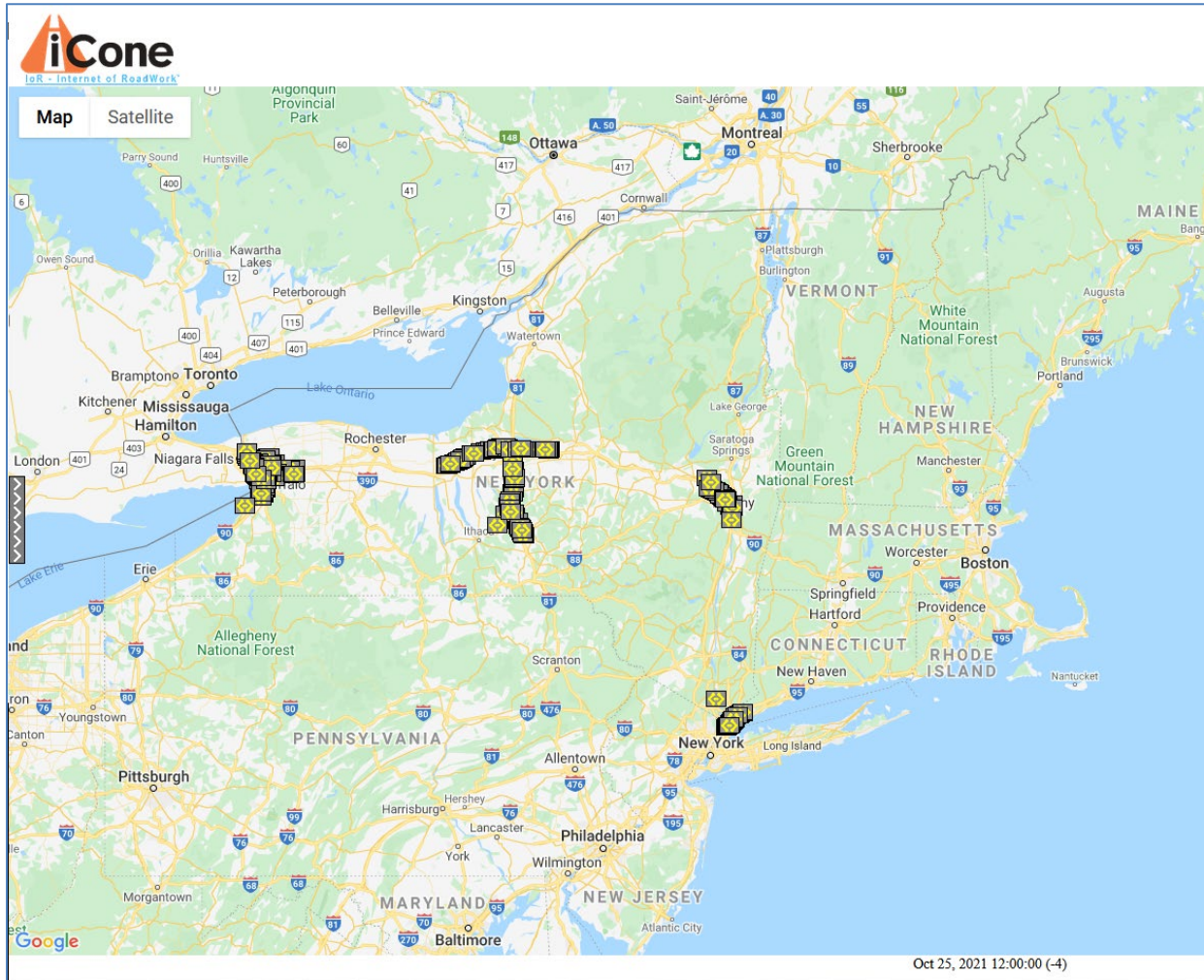
### 5.1.4 Arrow Board Kit Utilization

The iCone ConnectedTech product line is intentionally diverse to provide connectivity to a wide variety of temporary traffic control situations. After its introduction, the market was receptive to the Work Zone Connectivity Box in the form of the Arrow Board Kit. The NITTEC agencies requested a total of 11 Arrow Board Kits. The iCone engineers travelled to the NITTEC region three times to help install these units. Erie County and DOT Region 5 had their units installed on arrow boards that were attached to trailer mounted TMAs). The NYSTA had Arrow Board Kits installed on trailer mounted arrow boards.

The value of connecting the arrow boards was quickly noted by the senior management of the Thruway in Albany. The senior management asked that any unused arrow board kits be placed on loan to other Thruway facilities. In the end, a total of five arrow board kits were installed on Thruway arrow boards, and one unit was installed on DOT Region 3 trailer mounted TMA.

### Figure 7. Regional Usage of Arrow Board Kits

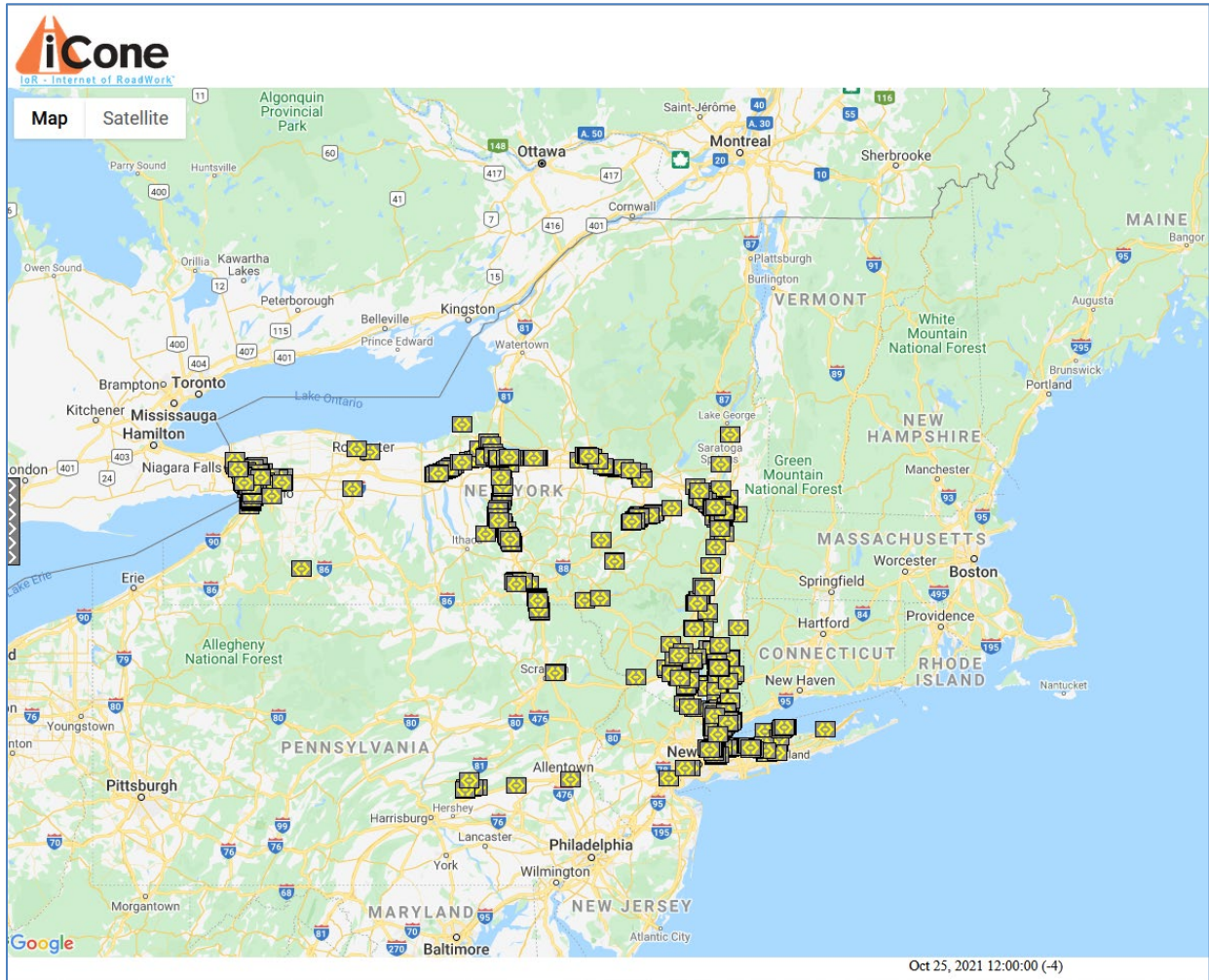
Location reports from Arrow Board Kits, Quarter 1, 2018 through Quarter 2, 2021.



Unlike the iBarrel, iPin, and Flagging Baton, the ConnectedTech Arrow Board Kit requires no action by the workers in order for it to function. As a result, once the agency installs the Arrow Board Kit the implementation of the technology proceeds for years without error. Figure 7 shows the deployments of the Arrow Board Kits procured for the project from 2018 through the third quarter of 2021.

**Figure 8. Statewide Usage of Arrow Board Kits**

Location reports from Arrow Board Kits, Quarter 1, 2018 through Quarter 2, 2021.



Since this project first deployed ConnectedTech Arrow Board Kits in New York State, the highway industry in the State has begun to adopt the technology for the safety of the workers. The NYSTA has begun to have their new TMA trucks built with Arrow Board Kits installed at the manufacturer. At least a dozen private contractors have also begun to adopt these connected arrow boards. As a result, the construction industry in the State of New York are leaders in the generation of work zone data and the distribution of that data to the driving public. Figure 8 shows the sites at which the iCone ConnectedTech Arrow Board Kits have been deployed by both public and private entities from 2019 through the third quarter of 2021.

## 5.2 Nationwide Findings

This underutilized technology project based in the Buffalo region has introduced a series of connected work zone technologies to New York State at the same time these technologies have been in trials at contractors and agencies across North America. More than half of the state departments of transportation and more than 100 private contractors have chosen to use one or more of these tools. This large pool of formal and informal trials have produced both engineering and market results that mirror this project’s outcomes.

iCone has had five major products in the North American market over the three years of the project. With the exception of the Truck Hazard Light Kit, these are the same products that were utilized in the Buffalo region. The result of this extensive use across the industry is that even though the legacy product, the iBarrel, has had a significantly longer time to build market acceptance, the most widely used products are the Arrow Board Kit and the Hazard Light Kit.

**Table 4. National Distribution of Equipment Use by Type**

	Autonomous?	Reporting Devices 2021	Percent
Arrow Board Kit	Y	874	72.5
Truck Hazard Light Kit	Y	110	9.1
iBarrel (iCone V4.0)	N	91	7.5
iPin	N	84	7.0
Flagging Baton	N	47	3.9

iCone is extremely engaged with its user base and has learned some lessons that are very heavily reinforced.

### **5.2.1 Lessons Learned—Highways First**

While there are a number of smaller companies with a focus on flagging operations that would like to use digital marking to make their workers safer, the first concern for larger entities is to use the technology to mark the activities on the larger highways. Logically, investments in technology are applied to the projects that have the most exposure to traffic and the public in general, these are the projects on the limited access highways. The two primary products for work on the highways are the Arrow Board Kit for lane closures and the Truck Hazard Light Kit for work trucks at the work site.

### **5.2.2 Lessons Learned—Simplicity for Success**

The application of connected technologies for work zones may not require a large amount of worker interaction; however, increasing information sharing of work activity to the traveling public is actually a significant culture change for field workers. As with any shift in an industry's culture, changes require time and incremental successes in order to build adoption by the group.

iCone has found that in the first year of an agency's adoption of connected work zone processes, it is important to do things that produce results without requiring the work crews to do anything new. The Arrow Board Kit and Truck Hazard Light Kit both operate in a fully autonomous mode. There is no need for worker involvement to have success in communicating the status of the work zone to the public and these successes can be built up and shared with both workers and management early on in the adoption process.

### **5.2.3 Lessons Learned—Summary**

With the combined experience from hundreds of thousands of work zone events, the iCone team strongly suggest the following approach to adopting connected work zone technologies. First, upgrade the organizations' legacy fleet of arrow boards to a connected status. This will have the highest impact on the traveling public and safety for the least amount of money in the shortest period of time.

Second, promote this success through all levels of the organization from upper management to the newest member of the work crews. The success will make it easier to upgrade the hazard lights to connected status on the work trucks.

With both arrow boards and truck hazard lights showing up in navigation apps, these tools will be more reliable in reporting road work. Agencies can promote the value of connected work zone data in navigation apps to the driving public. Not only will this get the drivers in each region to use navigation apps and pay attention to construction alerts as they drive, but it will also build an understanding of the value of connecting work zones throughout the organization, from the upper management to the work crews.

Once the use of connected arrow boards and truck hazard lights have been a success and that success has been promoted both in the organization and throughout the traveling public, the culture of the agency will begin to shift. It will then become possible for work crews to utilize technologies like the iPin and Flagging Baton. Continued promotion of successes can cement the new practices and shift the organizational culture to promote increased safety practices.

# Appendix A. Example of iCone Extended Incidents Feed (XML)

---

If the appendices are previously completed documents such as entire reports or scans of historical documents, they can simply be added in behind a flysheet with appendix A (or whatever is appropriate) listed on that page (as described in the next paragraph). It is not appropriate to reformat those documents.

For original information, appendices should use the same styles as the rest of the document. The page numbering is a little different as explained in the Report Formatting Guide and noted in this example. For example, the heading Appendix is Heading 1 No Number and the text should be Body Text style. Any figures or tables should have appropriate numbering, title, caption or header, and table text, respectively, as outlined in the Formatting Guide and Example.

## A.1 Extended Incidents Feed—Descriptions

Based on the Waze incident feed:

<https://developers.google.com/waze/data-feed/incident-information>

[http://www.gstatic.com/road-incidents/incidents\\_feed.xsd](http://www.gstatic.com/road-incidents/incidents_feed.xsd)

Additional iCone data elements:

"sensor" element: A traffic sensor location associated with the incident

type := The type of the traffic sensor

- "iCone" for an iCone speed barrel

id := A unique identifier string for this sensor location within the incident (at this time)

latitude := The defined GPS latitude for this sensor location, if available

longitude := The defined GPS longitude for this sensor location, if available

"radar" element: Radar details for a sensor element

devID := A unique identifier for the device which reported the radar data

intervalEnd := The timestamp of the end of the radar data sampling interval

latitude := The reported GPS latitude associated with this radar data, if available

longitude := The reported GPS longitude associated with this radar data, if available

numReads := The number of radar readings made during this data interval

avgSpeed := The average speed, in mph, for the radar readings made during this data interval

stDevSpeed := The weighted standard deviation, in mph, of the speed readings made during this data interval

"display" element: A displayed message location associated with the incident

type := The type of the messaging device

- "PCMS" for a Portable Changeable Message Sign trailer

- "AB" for an Arrow Board

- "Signal" for a portable traffic signal

id := A unique identifier string for this display location within the incident (at this time)

latitude := The defined GPS latitude for this display location, if available

longitude := The defined GPS longitude for this display location, if available

"message" element: Message details for a display element

verified := The timestamp that the message was verified as being displayed

text := The displayed message text. " / " used to separate lines, and " // " used to separate frames (or pages)

indicator := The meaning of an indication symbol, i.e. "Merge Right", "Merge Left", "Merge Left or Right", "Caution"

latitude := The reported GPS latitude associated with this displayed message, if available

longitude := The reported GPS longitude associated with this displayed message, if available

"marker" element: A marker of a generic location or device within the incident

type := The type of device used for this marker

- "iPin" for an iPin marker

- "Baton" for a Baton marker

- "Truck Beacon" for a truck mounted beacon

id := A unique identifier string for this marker location within the incident (at this time)

latitude := The defined GPS latitude for this sensor location, if available

longitude := The defined GPS longitude for this sensor location, if available

description := A manual description of the marker. Frequently, the descriptions will start with a common aspect of the incident, i.e. "beginning" or "end"



"status" element: Device Status details for a marker, display, or sensor element

type := The type of status report being made

- "iPin" for an iPin state (Active/Off)
- "Baton" for a Baton state (Active/Off)
- "Truck Beacon" for a Truck Beacon state (Active/Off)
- "Display Down" for a Display "Down" verification switch (Down/Up -

technically up=NOT verified as down)

- "Display Up" for a Display "Up" verification switch (Up/Down -

technically, down=NOT verified as up)

- "TMA Stowed" for a TMA "Stowed" verification switch

(Stowed/Deployed - technically, deployed=NOT verified as stowed)

starttime := The timestamp of the first occurrence of this state

verified := The timestamp of the most recent verification of this state

state := The reported state of this device/marker

## A.2 Extended Incidents Feed

```
<?xml version="1.0" encoding="UTF-8"?>
<incidents timestamp="2021-02-24T19:47:02Z">
  <incident id="U13631582_202102241818">
    <creationtime>2021-02-24T18:18:00Z</creationtime>
    <updateatime>2021-02-24T19:42:00Z</updateatime>
    <type>CONSTRUCTION</type>
    <subtype>HAZARD_ON_ROAD_LANE_CLOSED</subtype>
    <description>Roadwork - Lane Closed, MERGE RIGHT [Trafficade, iCone]</description>
    <location>
      <direction>ONE_DIRECTION</direction>
      <polyline>33.4936922,-112.2839194,33.4936922,-112.2839194</polyline>
    </location>
    <starttime>2021-02-24T18:18:00Z</starttime>
    <display type="AB" id="13631582" latitude="33.4936922" longitude="-112.2839194">
      <message verified="2021-02-24T19:42:00Z" indicator="Merge Right"
latitude="33.4937056" longitude="-112.2838784" />
```

```

    <status type="Arrow Panel" starttime="2021-02-24T14:56:03Z" verified="2021-02-
24T19:42:00Z" state="Right Chevron" />
    <status type="Display Down" starttime="2021-02-08T09:51:15Z" verified="2021-02-
24T19:42:00Z" state="Up" />
  </display>
</incident>
<incident id="U13631586_202102241656">
  <creationtime>2021-02-24T16:56:03Z</creationtime>
  <updatetime>2021-02-24T19:43:00Z</updatetime>
  <type>CONSTRUCTION</type>
  <subtype>HAZARD_ON_ROAD_LANE_CLOSED</subtype>
  <description>Roadwork - Lane Closed, MERGE RIGHT [Trafficade, iCone]</description>
  <location>
    <direction>ONE_DIRECTION</direction>
    <polyline>31.9655737,-110.2682589,31.9655737,-110.2682589</polyline>
  </location>
  <starttime>2021-02-24T16:56:03Z</starttime>
  <display type="AB" id="13631586" latitude="31.9655737" longitude="-110.2682589">
    <message verified="2021-02-24T19:43:00Z" indicator="Merge Right"
latitude="31.9655872" longitude="-110.2683136" />
    <status type="Arrow Panel" starttime="2021-02-24T16:56:03Z" verified="2021-02-
24T19:43:00Z" state="Right Chevron" />
    <status type="Display Down" starttime="2021-01-11T18:59:13Z" verified="2021-02-
24T19:43:00Z" state="Up" />
  </display>
</incident>
<incident id="U11534664_202102241640">
  <creationtime>2021-02-24T16:40:00Z</creationtime>
  <updatetime>2021-02-24T19:45:00Z</updatetime>
  <type>CONSTRUCTION</type>
  <description>Temporary traffic signal, be prepared to stop [Site-Safe, iCone]</description>
  <location>
    <direction>ONE_DIRECTION</direction>
    <polyline>37.2890900,-86.2845797,37.2890900,-86.2845797</polyline>

```

```

</location>
<starttime>2021-02-24T16:40:00Z</starttime>
<display type="Signal" id="11534664" latitude="37.2890900" longitude="-86.2845797">
  <status type="Signal" starttime="2021-02-24T14:09:00Z" verified="2021-02-24T19:45:00Z"
state="ACTIVE" />
</display>
</incident>
<incident id="U13631692_202102241715">
  <creationtime>2021-02-24T17:15:00Z</creationtime>
  <updatetime>2021-02-24T19:44:00Z</updatetime>
  <type>CONSTRUCTION</type>
  <subtype>HAZARD_ON_ROAD_LANE_CLOSED</subtype>
  <description>Roadwork - Lane Closed, MERGE LEFT OR RIGHT [WSDOT,
iCone]</description>
  <location>
    <direction>ONE_DIRECTION</direction>
    <polyline>46.9966344,-122.9055296,46.9966344,-122.9055296</polyline>
  </location>
  <starttime>2021-02-24T17:15:00Z</starttime>
  <display type="AB" id="13631692" latitude="46.9966344" longitude="-122.9055296">
    <message verified="2021-02-24T19:44:00Z" latitude="46.9965088" longitude="-
122.9056128" />
    <status type="Arrow Panel" starttime="2021-02-24T13:43:06Z" verified="2021-02-
24T19:44:00Z" state="Double Arrow" />
    <status type="Display Up" starttime="2020-10-20T14:23:53Z" verified="2021-02-
24T19:44:00Z" state="Down" />
  </display>

```

# Appendix B. iCone ConnectedTech Product Fact Sheets



## Welcome to ConnectedTech by iCone

ConnectedTech™ is a suite of technology devices that interface with existing traffic control equipment. Once deployed, our interrelated products intelligently report work zone data directly to navigation systems and in-dash of connected cars.

The platform improves safety for drivers and workers, travel times, and eventually, will aid the real-time decisions of vehicles as they approach active work areas.

*Whether your traffic management and safety equipment are from one manufacturer or several, iCone's ConnectedTech products work with all of them; giving you peace of mind and a single source to monitor work zone information from.*



## Work Zone Queue Management



The iCone locates itself, monitors traffic speed and links to the web and looks like an ordinary traffic barrel to the public. Whether you need to undertake work zone planning, work zone management or traffic monitoring, the iCone will provide you with real time information on traffic patterns to enable you to efficiently manage the traffic in a work zone. By strategically placing iCones while the project is underway, the traffic manager can monitor the effectiveness of traffic control plans and make informed modifications to it as necessary. It is easy to collect metrics on traffic flow through work zones using iCones pre-programmed tools. Drop one on the shoulder and flip a switch. The iCone™ locates itself using GPS, monitors speeds, and links to the web to begin monitoring the

## Information and Reports

The iCone System can quickly give you information about your work zone. Reports are immediately available that provide, for example, the location of the end of the queue, travel time through the work zone, speeds at the taper, or speeds at another location where worker or motorist safety may be a concern. The iCone™ system is preprogrammed to collect these and other metrics.



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*iCone, strategically placed, has led to a 45% reduction of rear-end collisions in active work zones.*

## Technical Features



### Manage Assets

- The iCone is able to sync with all iCone Traffic Devices
- System managers can review multiple roadwork devices
- Details on each device (Position, Battery Life, Historic Metrics)
- Most comprehensive integrated ITS portfolio



### Ease of Use

- Sets up in minutes along the roadside
- Remotely operate & monitor via Laptop, Smartphone, and Desktop
- Integrates with other iCone's in work zone
- Immediate communication to message boards



### Monitor

- Generates reports immediately
- Locates the end of the queue
- Calculates travel time through work zone
- Complete integration with all iCone devices

## Product Specifications

Weight: 75 lbs

Dimensions: 40 in tall, 26 in diameter

Battery: 12v, sealed, AGM battery

Material: LDPE (low density polyethylene)



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The platform improves safety for drivers and workers, travel times, and eventually, will aid the real-time decisions of vehicles as they approach active work areas.

*Whether your traffic management and safety equipment are from one manufacturer or several, iCone's ConnectedTech products work with all of them; giving you peace of mind and a single source to monitor work zone information from.*



## ConnectedTech iPin™

### Connect your Work Zone

The ConnectedTech iPin is a very manageable and portable device that acts like a beacon immediately alerting of any work activities involving human, vehicular, or road equipment.

The iPin can also be used as a geometric guide to plot the start/end of a work zone or when strategically placed, multiple iPins can delineate the geolocation of your defined construction areas or work zones.

***Reduce highway accidents by putting your workzone on the map.***

### “Drop a Pin” and put your Workers on the Map

Everyone is concerned about the safety of the workers while the drivers are piloting an active work zone. Advanced warning of an approaching work zone is one way to improve safety. The ConnectedTech iPin acts like a geometric marker, providing real time situational awareness of your work zone and digitally marking its vulnerable locations, ultimately providing the needed digital protective fence.

Upon deployment, the iPin notifies navigation apps, connected automobiles, traffic control centers, and onsite project managers of its GPS location and time.

The ConnectedTech iPin form factor allows it to be easily deployed inside traffic cones or on stationary equipment or utility vehicles.



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On-site project management interface

## Technical Features



### Data Recording

On-site activation / deactivation creates a record of activity as a live stream or XML data.

Data stream to navigational apps (e.g. Waze)



### Low Maintenance

Self-contained solar powered unit requires limited maintenance.



### Setup Geo-Zone (Boundary)

Arrange multiple iPin(s) to define boundaries that outline vulnerable areas in the work zone.



## Product Specifications

Weight: 1.0 lbs (453 grams)

Dimensions: 26in length, 1.5in diameter

Material: Polycarbonate (PET-G)

Battery: Exceeds 100hrs based on local solar conditions



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# Flagging Baton

ConnectedTech™

## Welcome to ConnectedTech by iCone

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The platform improves safety for drivers and workers, travel times, and eventually, will aid the real-time decisions of vehicles as they approach active work areas.

*Whether your traffic management and safety equipment are from one manufacturer or several, iCone's ConnectedTech products work with all of them; giving you peace of mind and a single source from which to monitor work zone information.*



## ConnectedTech Flagging Baton™

### Connect your Workers



The ConnectedTech™ Flagging Baton is an easily deployed technology adaptation to the stop paddle typically used by flaggers, crossing guards, and utility workers that broadcasts their positions to the data systems of navigation providers.

Further, with the flip of a switch, the Flagging Baton can broadcast if the lane is stopped or is being allowed to proceed slowly. The Flagging Baton also serves as a record keeping tool that can track the activity of the user.

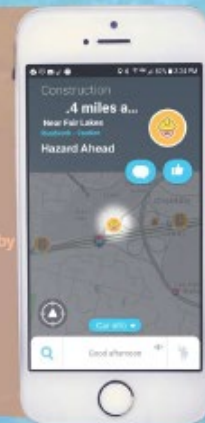
### Making it Safer to Step into Traffic

Some of the most hazardous procedures on the roadway, include humans that must step into traffic's path to provide directions. These operations, such as flagging and crossing guard are both dangerous jobs and have a significant impact on overall mobility. With a simple modification to a stop paddle to digitally broadcast the user's position, they can become part of the crowd sourced data environment and increase their safety as they step into traffic.



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The ConnectedTech Flagging Baton provides the GPS location and the expected delay that is being created by the paddle operator and passes it to the navigation devices miles before the road work allowing drivers the option of choosing alternate routes avoiding the minutes idling and increasing safety for all.

## Technical Features



### Record Keeping

- Daily or weekly activity reports.
- Flagging Start and Stop times.
- Start/Stop cycles are a timekeeping tool.
- Transmits flagging hold times every 10 minutes.
- Detects when paddle is laid down or traveling at vehicle speeds without being turned off.



### Position

- Once activated, Transmits GPS location and 'ON' status. Status posted to XML within 5 minutes.
- Once deactivated, Transmits GPS location and 'OFF' status. Status posted to XML within 60 seconds.
- Information is transferred to Navigation Systems (e.g. Waze) and available for automobile in-dash systems.
- Re-transmits location and status if moves more than 500 ft.

## Technical Specifications

Size: 10.5in cylinder, 1.5in diameter  
Weight: .56lbs (255 grams)

Temp range: -20C to +85C  
Power: Micro-USB charger for  
12 VDC or 110 VAC



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## Welcome to ConnectedTech by iCone

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The platform improves safety for drivers and workers, travel times, and eventually, will aid the real-time decisions of vehicles as they approach active work areas.



*Whether your traffic management and safety equipment are from one manufacturer or several, iCone's ConnectedTech products work with all of them; giving you peace of mind and a single source to monitor work zone information from.*

## ConnectedTech AB (Arrow Board) Kit

### Connect your Arrow Boards

Real-time information about the status & state of your arrow boards.

The Arrow Board Kit will transform your arrow boards to have the ability to transfer data over a cloud network without human interaction and enhance the capabilities of your equipment.

By implementing these devices into your road work zone, you can improve proactive management of traffic conditions.

*This leads to improved safety for agencies by knowing all closures.*



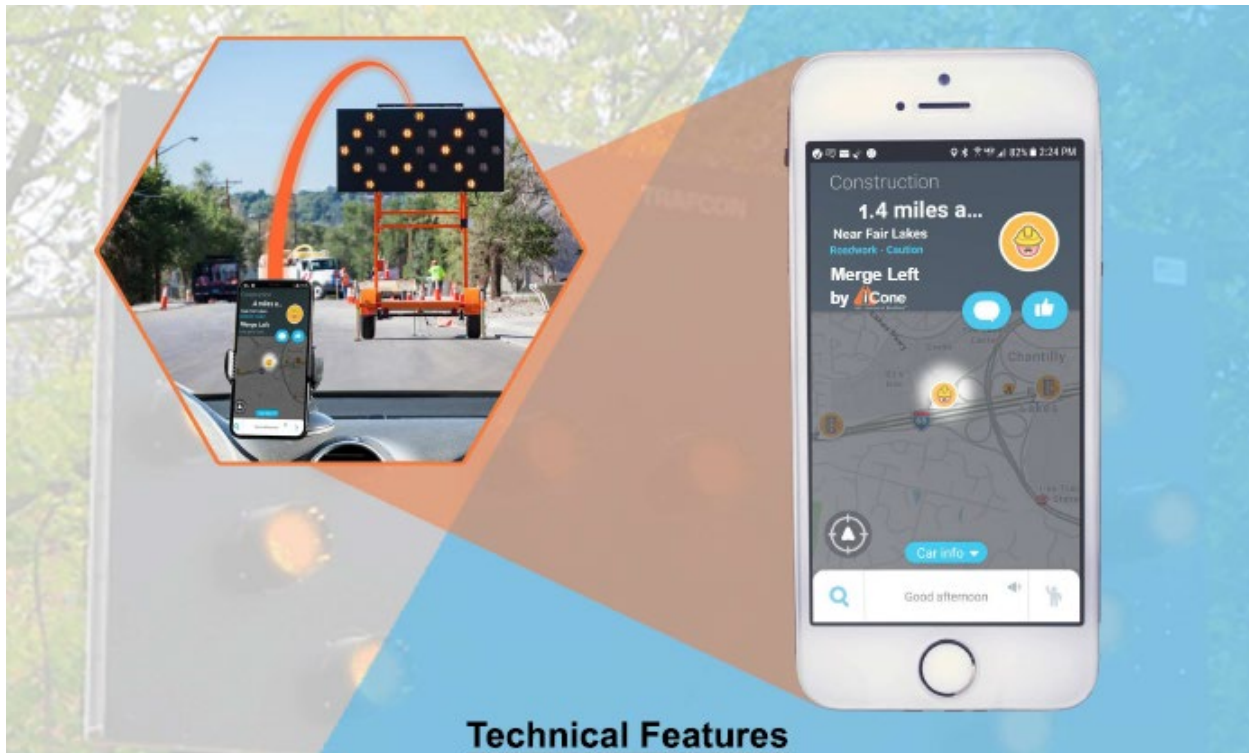
### Make your Work Zones Safe, Smart & Compliant!

As State DOTs start mandating that work zone equipment, especially Arrow Boards, are connected to mapping, navigation, and trip-routing systems, the Arrow Board kit can be quickly retrofitted to existing panels. iCone is currently working with OEM developers to have new panels already outfitted with the Arrow Board Kit.

*Contact your arrow panel manufacturer to inquire if they are powered by ConnectedTech from iCone.*



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## Technical Features

The ConnectedTech Arrow Board Kit provides the following comprehensive information on the operation management and health of your arrow panels:



### Position

- Once activated, Transmits GPS location and 'ON' status of the Board.
- Once deactivated, Transmits GPS location and 'OFF' status of the Board. Updates location and 'OFF' status at 4 hour intervals.
- Information is transferred to Navigation Systems (e.g. Waze) and available for automobile in-dash systems.



### Arrow Mode

- Determines if the arrows are in the following modes:
  - LEFT/RIGHT/DOUBLE (Static Arrow, Moving Arrow, Sequential Arrow, Sequential Chevrons)
  - CAUTION (Flashing Corners, Flashing Line, Alternating Diamond)



### Board Status

- Once activated Status of your arrow board is posted to XML within 2 minutes.
- Upon deactivation, Status posted to XML within 60 seconds.
- Transmits Arrow Panel status every 15 minutes.
- Re-transmits location and status if the Arrow Panel moves more than 300 ft.



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# Hazard Light Kit

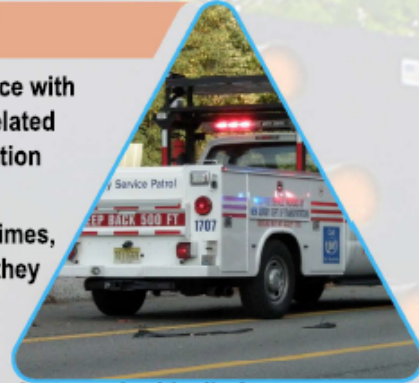
ConnectedTech™

## Welcome to ConnectedTech by iCone

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The platform improves safety for drivers and workers, travel times, and eventually, will aid the real-time decisions of vehicles as they approach active work areas.

*Whether your traffic management and safety equipment are from one manufacturer or several, iCone's ConnectedTech products work with all of them; giving you peace of mind and a single source from which to monitor work zone information.*



## ConnectedTech Hazard Light Kit™

### Connect your Fleets

The ConnectedTech™ Hazard Light Kit is a safety transponder that helps reduce distracted driver vehicular incidents by alerting the public in advance when vulnerable workers and/or their vehicles are in the field.

The Hazard Light integrates with the hazard/flashing lights and other peripherals (arrow boards, attenuators, booms) as mounted on most traffic control, maintenance, roadside service, and utility vehicles in your fleet. Providing comprehensive awareness of your vehicle's location and the current mode of operation of its other alert attachments.



### Advanced Collision Protection

Help protect your work crews, vehicles, and assets as they perform their daily tasks.

The ConnectedTech Hazard Light digitally connects any vehicle in your fleet, intentionally providing an extra layer of protection to keep responders, roadside operators and workers safe while on the road.

The Hazard Light acts like a beacon providing advanced warning inside their vehicles to approaching motorists when crews are on-scene nearby.



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## Technical Features



### Vehicle Info

- Digitally Connects any fleet vehicle.
- Transmits vehicle ID and location



### Position

- Once activated, Transmits GPS location and 'ON' status. Status posted to XML within 2 minutes.
- Information is transferred to Navigation Systems (e.g. Waze) and available for automobile in-dash systems.
- Re-transmits location if the vehicle moves more than 500 ft



### Hazard & Signal Modes

- Connects to the hazard Lights and other peripherals and reports the following modes:
- Hazard Lights:
    - Determines if Lights are on/off
  - Arrow Boards: Determines position of Arrow board Up/down/stored
  - Boom position: Determines if a boom is up/down

## Technical Specifications

Size: 6in x 4in x 2in  
 Weight: .62lbs (283.5 grams)

Temp range: -20C to +85C  
 Power: wires to 12VDC power and flasher



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