DOT PHMSA Internal Quarterly Report

Date of Report: 3rd Quarterly Report - April 1 through June 30, 2020 – rev1
Contract Number: 693JK31910007
Prepared for: USDOT PHMSA and Operations Technology Develop LLC (OTD)
Project Title: Develop and Demonstrate a Remote Multi-Sensor Platform for Right-of-Way Defense
Prepared by: Gas Technology Institute
Contact Information: Mike Adamo, 847-454-3428, madamo@gti.energy
For quarterly period ending June 30, 2020

1: Items Completed During this Quarterly Period:

Figure 1. Payable Milestones Completed this Quarter

Technical and Deliverable Milestone Schedule						
Item #	**Task #**	**Activity/Deliverable**	**Title**	**Federal Cost**	**Cost Share**	**Total**
3	1	Technology Review	Provide a final list of features of and improvements to the ROW Defense technology that will be adhered to for the balance of the project. Provide a list of potential utility test sites. Provided within a quarterly report.	4,444.00	4,134.00	8,578.00
4	2	Hardware Improvements	A set of hardware requirements that incorporate the TAP feedback captured during Task 1. Provided within a quarterly report.	17,126.00	26,897.00	44,023.00
8	2	Hardware Improvements	Identify alternative hardware products that can reduce the size and power consumption of the ROW Defense System. Provide a list of the selected devices. Verify costs and delivery times. Provided within a quarterly report.	12,947.00	20,169.00	33,116.00
11	6		Submit 3rd quarterly report	3,392.00	4,086.00	7,478.00

This table was populated with Items from Attachment #3, Technical and Deliverable Payable Milestone Schedule (in the contract) that were completed during this reporting period and are the corresponding Items included on our next invoice.

2: Items Not-Completed During this Quarterly Period:

This project is currently one quarter behind schedule. The OTD co-funding contract was finalized during December of 2019. Given the requirement to coordinate the PHMSA and OTD budgets, very little effort was expended during the first project quarter. It remains to be seen how the pandemic affects utility and equipment vendor schedules.

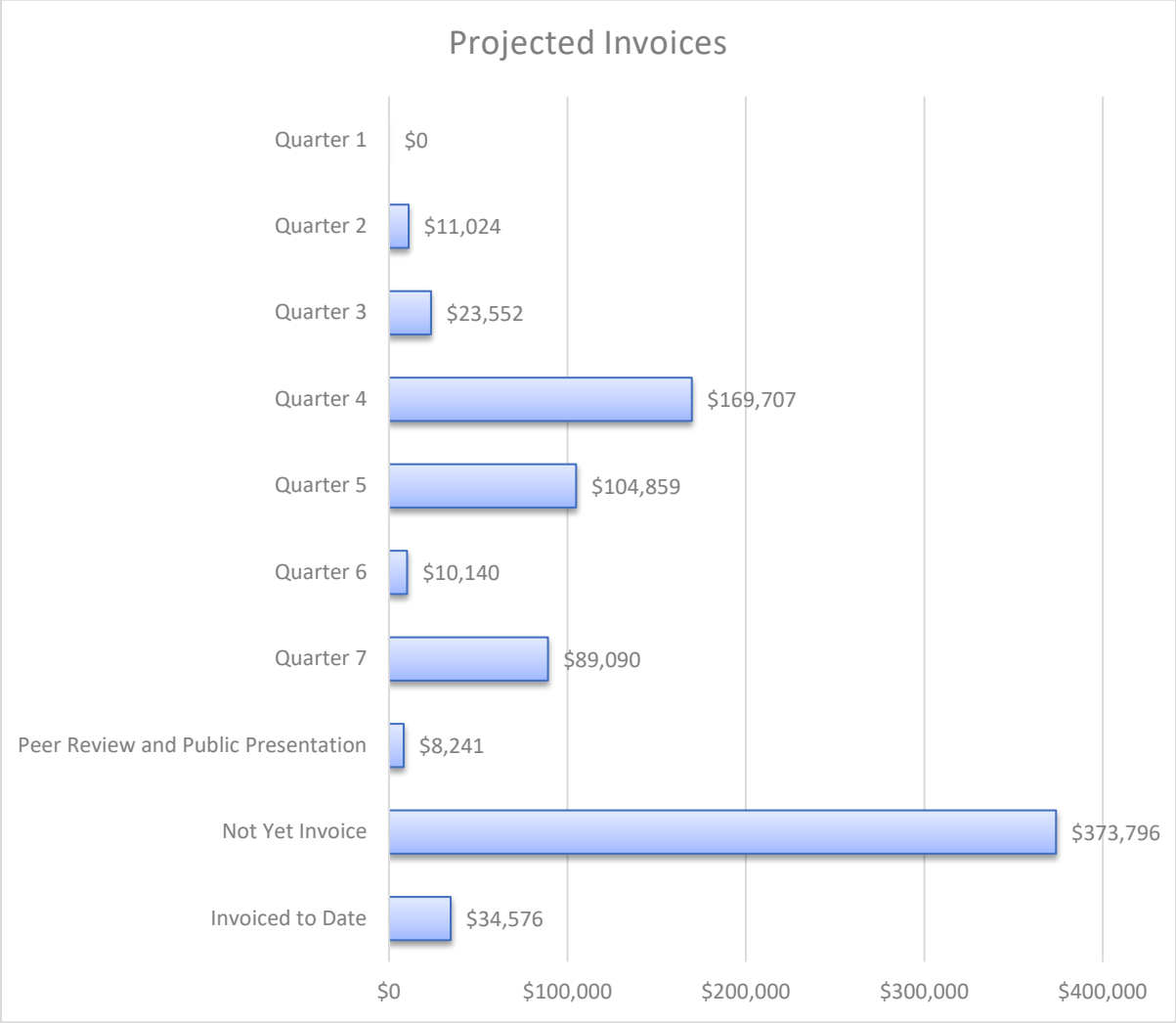
Figure 2. Payable Milestones Not Completed this Quarter

Technical and Deliverable Milestone Schedule						
Item #	**Task #**	**Title**	**Activity/Deliverable**	**Federal Cost**	**Cost Share**	**Total**
5	3	Data Management and Analytics	Review Open Geospatial Consortium (OGC) standards for representing sensor data, review current state of available Geographic Information System (GIS) tools, and create a list of the specific tools to be used in this project. Provided within a quarterly report.	47,939.00	22,806.00	70,745.00
6	4	User Interface Improvements	A set of user interface requirements that incorporate the TAP feedback captured during Task 1. Provided within a quarterly report.	12,096.00	15,291.00	27,387.00
9	3	Data Management and Analytics	Set up and maintain for the duration of the project a GIS environment to capture and visualize data collected from the various test sites. Provide stakeholders login credentials. Provide basic training on usage.	36,436.00	19,395.00	55,831.00
10	4	User Interface Improvements	Provide a demonstration of improved ability of the dashboard to drill down to details and to present warnings and alerts.	10,973.00	12,072.00	23,045.00

3: Project Financial Tracking During this Quarterly Period:

The nature of the contract for this research effort is fixed price, with clearly defined milestone/deliverable payments. **Figure 2** below outlines projected invoicing, as well the invoice submitted upon delivery of the first payable milestone.

Figure 2. Quarterly Payable Milestones/Invoices - 693JK31910007 (Federal Costs)



4: Project Technical Status

ACTIVITY: TECHNOLOGY REVIEW AND TECHNICAL ADVISORY PANEL (TAP)

Item Title: Notes of Kickoff Meeting Detailing any Project Scope Changes
Item Number: 1
Task Number: 1

The project kick-off meeting was held with GTI and DOT/PHMSA January 16, 2020. The participants included: Michael Adamo/GTI, Matt Manning/GTI, Chris Ziolkowski/GTI, Rob Marros/GTI, and Chris Hoidal/DOT PHMSA.

This item is complete.

ACTIVITY: SUBMIT 1ST QUARTERLY STATUS REPORT

Item Title: 1st Quarterly Report
Item Number: 2
Task Number: 6

This item was completed on December 31, 2019.

ACTIVITY: TECHNOLOGY REVIEW TAP FEEDBACK

Item Title: Capture TAP Feedback
Item Number: 3
Task Number: 1

This item was completed. The list of current features of and proposed improvements to the ROW Defense technology were presented to the TAP members. Figure 3 is a functional block diagram of a remote sensor installation for a ROW monitor system currently deployed.

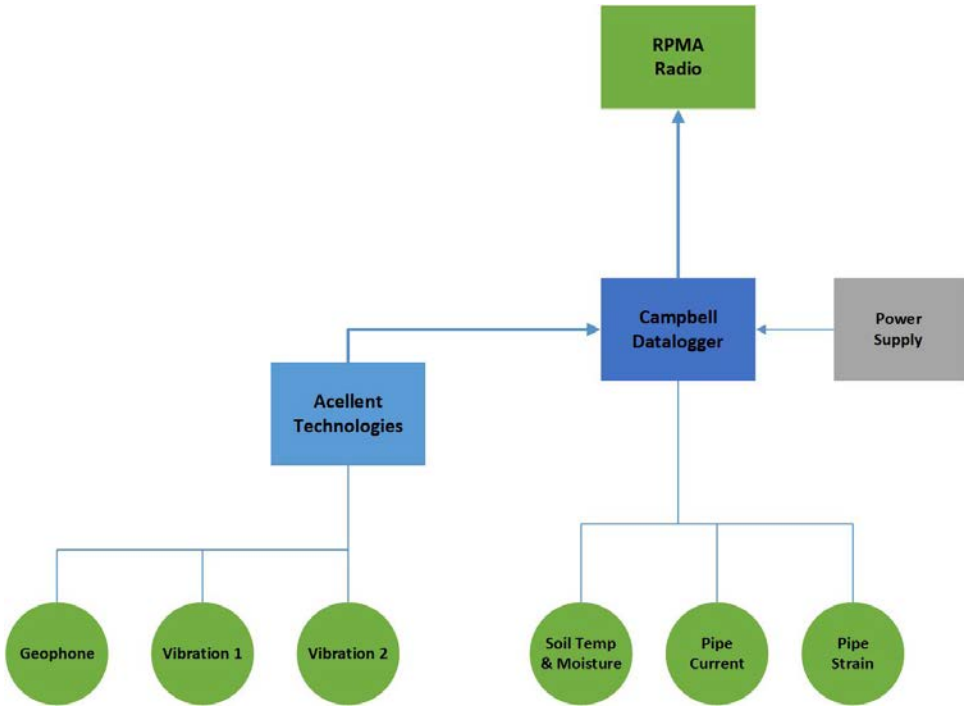


Figure 3. ROW Monitor Sensor Installation - Present

TAP feedback as to additional features was received. Two items that were of interest to the TAP were the ability to detect the presence of gas and lightning detection.

ACTIVITY: HARDWARE IMPROVEMENTS

Item Title: Develop Hardware Requirements
Item Number: 4
Task Number: 2

This item was completed. Figure 4 is a functional block diagram of the sensor installation currently under development. It will maintain compatibility with the below ground suite of sensors that were tested in the prior project. An additional set of above ground sensors will also be added. In addition to the gas and lightning detection capabilities asked for by the TAP, acoustic microphones will be incorporated. The motivation for this is that sound may be a useful corollary in the identification of machinery operating in the ROW or in detecting thunder. The sub processors that will handle these sensors and the sensor support libraries are currently under development. These are discussed in greater detail below.

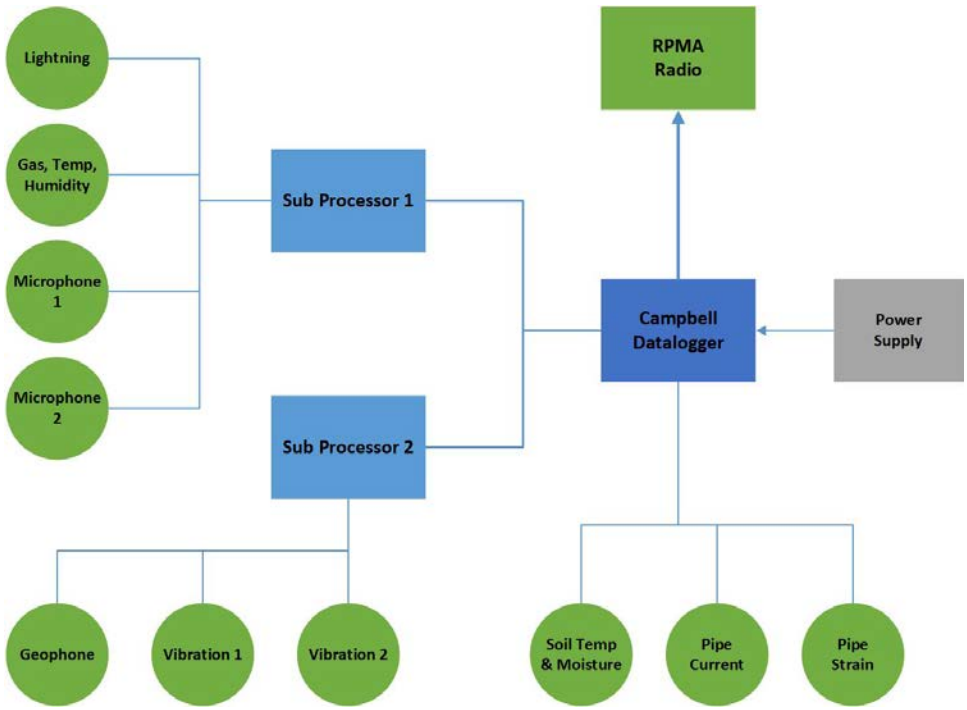


Figure 4. ROW Monitor Sensor Installation - Future

ACTIVITY: DATA MANAGEMENT AND ANALYTICS

Item Title: Review of GIS Standards and Tools
Item Number: 5
Task Number: 3

This item is partially complete: Review Open Geospatial Consortium (OGC) standards for representing sensor data, review current state of available Geographic Information System (GIS) tools, and create a list of the specific tools to be used in this project. Provided within a quarterly report.

As part of this task, GTI is cataloging and reviewing the OGC (https://www.ogc.org/docs/is) standards that exist for sensor data. There are many standards maintained by OGC that touch on the device (sensor thing) and data (data stream) that are utilized in this project. GTI has identified the following standards as applicable to this project. These standards are being reviewed to develop a gap analysis between the OGC standards for sensors and the devices and data being utilized in this project. Due to the generalized nature of the standards and the variations in potential sensor packages used, it is

expected that significant differences will exist between the standards and the devices used in this solution.

The following standards from the OGC.org website (OGC Standards n.d.) are related to the sensors and data used in this project and will be evaluated in-depth:

- SWE Common Data Model: The Sensor Web Enablement (SWE) Common Data Model Encoding Standard defines low-level data models for exchanging sensor-related data between nodes of the OGC® Sensor Web Enablement (SWE) framework. These models allow applications and servers to structure, encode, and transmit sensor datasets in a self-describing and semantically enabled way.
- SWE Service Model: This standard currently defines eight packages with data types for common use across OGC Sensor Web Enablement (SWE) services. Five of these packages define operation request and response types. The packages are:
    1. Contents – Defines data types that can be used in specific services that provide (access to) sensors;
    2. Notification – Defines the data types that support the provision of metadata about the notification capabilities of a service as well as the definition and encoding of SWES events;
    3. Common – Defines data types common to other packages;
    4. Common Codes –Defines commonly used lists of codes with special semantics;
    5. DescribeSensor – Defines the request and response types of an operation used to retrieve metadata about a given sensor;
    6. UpdateSensorDescription –Defines the request and response types of an operation used to modify the description of a given sensor;
    7. InsertSensor – Defines the request and response types of an operation used to insert a new sensor instance at a service;
    8. DeleteSensor – Defines the request and response types of an operation used to remove a sensor from a service.
- Sensor Model Language: The primary focus of the Sensor Model Language (SensorML) is to provide a robust and semantically-tied means of defining processes and processing components associated with the measurement and post-measurement transformation of observations.
- Sensor Observation Service: The SOS standard is applicable to use cases in which sensor data needs to be managed in an interoperable way. This standard defines a Web service interface that allows querying observations, sensor metadata, as well as representations of observed features.
- Sensor Planning Service: The OpenGIS® Sensor Planning Service Interface Standard (SPS) defines interfaces for queries that provide information about the capabilities of a sensor and how to task the sensor. The standard is designed to support queries that have the following purposes: to determine the feasibility of a sensor planning request; to submit and reserve/commit such a request; to inquire about the status of such a request; to update or cancel such a request, and to request information about other OGC Web services that provide access to the data collected by the requested task.
- Sensor Things: The OGC SensorThings API provides an open, geospatial-enabled, and unified way to interconnect the Internet of Things (IoT) devices, data, and applications over the Web. At a high level, the OGC SensorThings API provides two main functionalities, and each function is handled by a part. The two parts are the Sensing part and the Tasking part. The Sensing part provides a standard way to manage and retrieve observations and metadata from heterogeneous IoT sensor systems. The Tasking part is planned as a future work activity and will be defined in a separate document as Part II of the SensorThings API.
- Semantic Sensor Network: The SSN ontology is an ontology for describing sensors and their observations, the involved procedures, the studied features of interest, the samples used to do so, and the observed properties, as well as actuators.

- Observations and Measurements: This standard specifies an XML implementation for the OGC and ISO Observations and Measurements (O&M) conceptual model (OGC Observations and Measurements v2.0 also published as ISO/DIS 19156), including a schema for Sampling Features. This encoding is an essential dependency for the OGC Sensor Observation Service (SOS) Interface Standard. More specifically, this standard defines XML schemas for observations, and for features involved in sampling when making observations. These provide document models for the exchange of information describing observation acts and their results, both within and between different scientific and technical communities.
- Pipeline Model Language: The OGC PipelineML Conceptual and Encoding Model Standard defines concepts supporting the interoperable interchange of data pertaining to oil and gas pipeline systems. PipelineML supports the common exchange of oil and gas pipeline information. This initial release of the PipelineML Core addresses two critical business use cases that are specific to the pipeline industry: new construction surveys and pipeline rehabilitation. This standard defines the individual pipeline components with support for lightweight aggregation. Additional aggregation requirements such as right-of-way and land management will utilize the OGC LandInfra standards with utility extensions in the future. Future extensions to PipelineML Core will include (non-limitative): cathodic protection, facility, and safety.

ACTIVITY: USER INTERFACE REQUIREMENTS

Item Title: Capture TAP feedback
Item Number: 6
Task Number: 4

This item is not complete: A set of user interface requirements that incorporate the TAP feedback captured during Task 1. Provided within a quarterly report.

This quarterly report will also be issued to the OTD sponsors for review. A TAP meeting will be called to capture any additional thoughts or feedback on the User Interface.

ACTIVITY: HARDWARE IMPROVEMENTS

Item Title: Identify Alternative Hardware Products
Item Number: 8
Task Number: 2

This item was completed. The team has worked to investigate new hardware and sensor options to optimize existing information collection and add additional sensing capabilities. A Campbell data logger will remain at the center of the station to aggregate various sensor readings and send them over the network using an attached RPMA radio. The original stations used the Campbell CR800 datalogger. The new stations will use the CR6 model that provides improved features such as removable storage, USB, WiFi, and Ethernet connectivity.

Independent “sub-processors” are being explored to offload some computationally intensive sensor collection activities from the data logger, freeing the data logger to focus on less-strenuous data capture and managing sensor payloads sent over the network. Two types of “sub-processors” are currently being evaluated, the STM32L476RG Nucleo board (Figure 5) and the Freescale MK20DX256 Teensy 3.2 (Figure 6).

Both boards contain a low-power ARM Cortex-M4 processor with built-in DSP accelerator. In both cases, there is a simple upgrade path to a Cortex-M7 processor available if greater capabilities are needed. The trade-off is that the programming environments are different. The STM32L476RG is a general-development board, which means that there is a learning curve to get familiar with the software tools and write the necessary drivers. The Teensy 3.2 has the advantage of being able to be integrated with the Arduino environment for rapid development along with readily available audio-libraries which are suited for interfacing microphones.

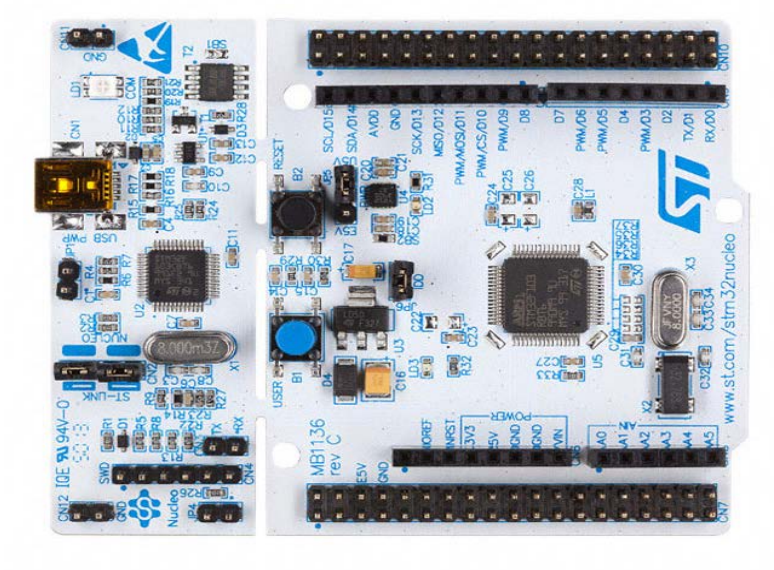


Figure 5. STM32L476RG Nucleo Board

Figure 6. Teensy 3.2

Microphones are being investigated to monitor any above-ground activity around the station. These audible-range MEMs microphones will allow activity such as construction equipment or other activities, potentially hazardous to the ROW, to be monitored. The microphones will be connected to one of the "sub-processors" where real-time peak and average sound level analysis will occur. Only a compressed summary of the audio activity for a given time period will be sent over the RPMA network. In instances where a sustained level of abnormally loud sound is observed, an immediate notification can be sent over the network alerting individuals of the situation. Additionally, machine learning (ML) based audio classification techniques are being explored that will help categorizes important sounds in the ROW. Using TensorFlow Lite, the classifications can occur locally and in real-time on the "sub-processor" at the station. This allows a high-bandwidth stream of microphone data to be efficiently represented as a single classifier label, better suited for a low-bandwidth connection such as RPMA.

A second "sub-processor" will be used to sample and collect geophone and pipe vibration data from the sensors installed in the ground at each station. Attributes such as peak and average signal, and frequency content will be calculated and passed to the data logger.

A lightning detection sensor AS3935 (Figure 7) is being investigated to monitor lightning activity near the sensor station. This can aid in root-cause analysis of a failure; lightning damage often goes undetected or misdiagnosed. The sensor was interfaced with a development platform to monitor for lightning and test the reliability and accuracy of the sensor. A basic web dashboard was used to monitor

the data and the sensor was left running 24/7. For further work, the sensor is to be deployed outdoors to see whether that changes the frequency of triggering.

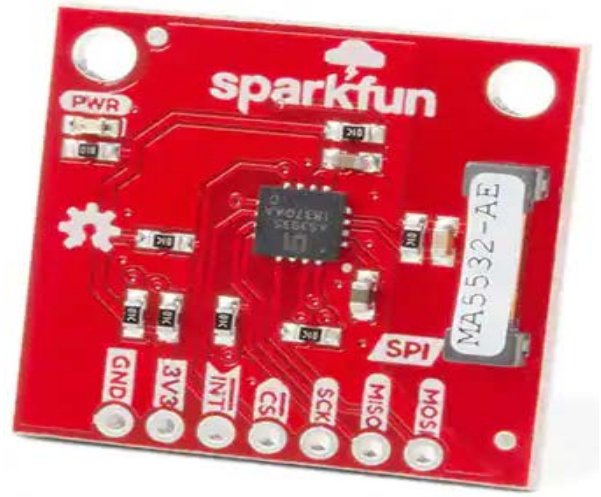


Figure 7 Lightning Detection Sensor (AS3935)

Also, there is work being done on interfacing methane gas leak sensors (Dynament and NevadaNano) with the STM32L476RG board. Previously created libraries for different development environments are being modified to function within the STM environment. The NevadaNano sensor is the preferred sensor since it can characterize gases, distinguishing methane from other flammables. At the time of writing this report, the sensor software libraries are in testing.

Activity: Data Management and Analytics

Item Title: Set up and Maintain a GIS Environment
Item Number: 9
Task Number: 3

This item is not complete: it is expected to commence next quarter.

Activity: User Interface Requirements

Item Title: Provide a Demonstration of User Interfaces Capabilities
Item Number: 10
Task Number: 4

This item is not complete: it is expected to commence next quarter.

Activity: Submit 3rd Quarterly Status Report

Item Title: 3rd Quarterly Report
Item Number: 11
Task Number: 6

This document is the completed, current quarterly report.

Activity: Project Management

Item Title: N/A
Item Number: N/A
Task Number: 6

During this quarter, GTI conducted project scheduling, budgeting, task/activity sequencing, preparation of reports, and coordination, organization, and facilitation of required meetings.

5: Project Schedule

The project schedule through June 30, 2020 (ending September 30, 2021) is shown below. The project is 3 months behind schedule. Progress on payable milestones (delineated by Item and Task number) are linked to the schedule and are also shown below for completeness.

Figure 8. Project Schedule

Task	Item	Title	% Complete	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
1	1	Technology Review TAP	100%								
1	3	Technology Review Reported	100%								
2	4	Hardware Improvements Requirements	100%								
2	8	Hardware Improvements Identify Products	100%								
2	12	Hardware Improvements Testing	0%								
2	17	Hardware Improvements Procurement	0%								
3	5	Data Management & Analytics Review	10%								
3	9	Data Management Set Up GIS	0%								
3	13	Data Management Machine Learning	0%								
3	18	Data Management Final Performance	0%								
3	24	Data Management Initial Performance	0%								
4	6	User Interface Improvements Requirements	0%								
4	10	User Interface Initial Demonstration	0%								
4	14	User Interface Verify GIS Connection	0%								
4	19	User Interface Final Demonstration	0%								
5	15	Deployment Confirm Test Sites	0%								
5	20	Deployment Installation Reported	0%								
5	22	Deployment 2nd Operation Report	0%								
5	25	Deployment 1st Operation Report	0%								
6		Project Management	30%								
				2019	2020				2021		

Figure 9. Item Progress

Technical and Deliverable Milestone Schedule						
Item No.	**Task No.** (per proposal)	Activity/Deliverable **ACTIVITY/DELIVERABLE**	Quarter No.	**Expected Completion Date/Mos**	**Payable Milestone** **TITLE**	**Item Progress**
1	1	Technology Review	1	3 months	List of members for a technical advisory panel (TAP) consisting of utilities and technology providers.	Complete
2		1st Quarterly Status Report	1	3 months	Submit 1st quarterly report	Complete
		First Payable Milestone	**1**	**3 months**	**SUBTOTAL**	Complete
3	1	Technology Review	2	6 months	Provide a final list of features of and improvements to the ROW Defense technology that will be adhered to for the balance of the project. Provide a list of potential utility test sites. Provided within a quarterly report.	Complete
4	2	Hardware Improvements	2	6 months	A set of hardware requirements that incorporate the TAP feedback captured during Task 1. Provided within a quarterly report.	Complete
5	3	Data Management & Analytics	2	6 months	Review Open Geospatial Consortium (OGC) standards for representing sensor data, review current state of available Geographic Information System (GIS) tools, and create a list of the specific tools to be used in this project. Provided within a quarterly report.	Not Complete
6	4	User Interface Improvments	2	6 months	A set of user interface requirements that incorporate the TAP feedback captured during Task 1. Provided within a quarterly report.	Not Complete
7	6	2nd Quarterly Status Report	2	6 months	Submit 2nd quarterly report	Complete
		Second Payable Milestone	**2**	**6 months**	**SUBTOTAL**	Not Complete
8	2	Hardware Improvements	3	9 months	Identify alternative hardware products that can reduce the size and power consumption of the ROW Defense System. Provide a list of the selected devices. Verify costs and delivery times. Provided	Complete
9	3	Data Management & Analytics	3	9 months	Set up and maintain for the duration of the project a GIS environment to capture and visualize data collected from the various test sites. Provide the test site hosts and other stakeholders login	Not Complete
10	4	User Interface Improvments	3	9 months	Provide a demonstration of improved ability of the dashboard to drill down to details and to present warnings and alerts.	Not Complete
11	6	3rd Quarterly Status Report	3	9 months	Submit 3rd quarterly report	Complete
		Third Payable Milestone	**3**	**9 months**	**SUBTOTAL**	Not Complete
12	2	Hardware Improvements	4	12 months	Procure equipment to facilitate hardware improvements and test improvements on pipe in GTI or utility test yard. Create a test report showing the performance of the equipment. Provided within a quarterly report	On Schedule
13	3	Data Management & Analytics	4	12 months	Investigate machine learning (ML) tools available for the selected GIS environment. Provide an assessment of their applicability to the expected test site data. Provided within a quarterly report	On Schedule
14	4	User Interface Improvments	4	12 months	Provide test data verifying that improved hardware can connect to GIS and to dashboard. Provided within a quarterly report.	On Schedule
15	5	Deploy System	4	12 months	Complete procedures and equipment list required to deploy the ROW Defense System on a test site. Finalized location of utility test sites. Schedule for deployment of equipment on test sites. Provided within a quarterly report	On Schedule
16	6	4th Quarterly Status Report	4	12 months	Submit 4th quarterly report	On Schedule
		Fourth Payable Milestone	**4**	**12 months**	**SUBTOTAL**	On Schedule
17	2	Hardware Improvements	5	15 months	Provide final test reports or needed clarifications showing the performance of the equipment as deployed. Provided within a quarterly report.	On Schedule
18	3	Data Management & Analytics	5	15 months	Summarize the performance and costs of maintaining GIS environment. Provided within a quarterly report	On Schedule
19	4	User Interface Improvments	5	15 months	Provide second and final demonstration of improved dashboard to TAP	On Schedule
20	5	Deploy System	5	15 months	Narrative describing the deployment of equipment on the utility test sites. The narrative will cover the installation process and any issues encountered. Provided within a quarterly report.	On Schedule
21	6	5th Quarterly Status Report	5	15 months	Submit 5th quarterly report	On Schedule
		Fifth Payable Milestone	**5**	**15 months**	**SUBTOTAL**	On Schedule
22	5	Deploy System	6	17 months	Narrative describing the operation of equipment on the utility test sites. The narrative will cover events observed or recorded on the test sites during the reporting period. Provided within a quarterly report	On Schedule
23	6	6th Quarterly Status Report	6	18 months	Submit 6th quarterly report	On Schedule
		Sixth Payable Milestone	**6**	**18 months**	**SUBTOTAL**	On Schedule
24	3	Data Management & Analytics	7	21 months	Final summary of the performance of GIS ML tools on data from the utility test sites. Provided within a quarterly report.	On Schedule
25	5	Deploy System	7	21 months	Narrative describing the operation of equipment on the utility test sites. The narrative will cover events observed or recorded on the test sites during the reporting period. Provided within a quarterly report	On Schedule
26	6	7th Quarterly Status Report	7	21 months	Submit 7th quarterly report	On Schedule
		Seventh Payable Milestone	**7**	**21 months**	**SUBTOTAL**	On Schedule
33		8th Quarterly Status Report	10	28 months	Submit draft final report with quarterly	On Schedule