Transitioning from Prototype to Production: The AC Pipe Scanner

March 5, 2019

Agreement Number: AI 2396A

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Funder: Alberta Innovates, SDTC

Project Partners: Surrey, BC; Taber, AB

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General Project Information

Proposal ID (from EOI):	#E3278022
Project Title:	The AC Pipe Scanner : Transitioning from prototype to production
Project Location(s):	Burnaby, BC
Anticipated Start Date:	January 1, 2017
Anticipated Completion Date:	February 28, 2019

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Sector (private, public, etc.):	private
Geographic location of major operations in Canada:	British Columbia
Legal Status*:	Incorporated
Date of Incorporation:	June 30, 2008
In business since:	2011
# of full time employees:	6
Ownership of major share structure:	Csaba Ékes, founder and president owns 100%

Executive Summary

Much of the water and wastewater industry's pipe networks are nearing the end of their design life and require replacement. This trend is occurring at the same time that municipal utility providers are facing major budget constraints. There is a need to provide measurable data in order to establish the extent of rehabilitation required or the timing of replacement for these pipes.

Asbestos cement (AC) pipe comprises a significant portion of water distribution systems in many North American cities. AC pipe was a popular choice of engineers for potable water, sanitary sewer, and storm drain pipelines during the 1940s, 50s, and 60s and an estimated 1,014,000 km of AC pipe were installed in Canada and in the US. About 12 to 15% of water mains in the water distribution systems of Canada and the USA are AC pipes.

Hundreds of thousands of miles of AC pipe are beyond or are approaching the end of their 50-year design lives. Alberta has approximately 9,513,000 m of Asbestos Cement pipe and failures are often daily events. Traditional Closed Circuit Television (CCTV), the most commonly used condition assessment method does not provide sufficient information to determine the remaining service life of these pipes, it does not provide accurate timelines for replacement, or predict future failure. Water is being lost, and sewage is being leaked into the environment. At the beginning of the project there was no technology on the market to assess the condition of these critical assets.

The objective of the project was to develop a pipe inspection system to assess the condition of AC (and other non-ferrous) pipes. The SewerVUE AC Pipe Scanner (ACPS) deploys high frequency radar antennas inside AC pipes to directly measure wall thickness, map defects, and detect voids outside the pipe and thereby provide complete condition assessment. While the company's pipe penetrating radar (PPR) technology has been used on large diameter non-ferrous sewer and water pipes, adapting and deploying this technology in water and sewer mains presents a significant technical challenge.

At the end of the project a prototype system was designed, built and tested in live sanitary sewers. The system can handle gravity pipes in the 10" to 15" range with an inspection distance up to 1000 m form a single entry point, together with the data collection, processing and reporting software. Inspection distance can be increased to 1500 m by switching to a fibre optic tether. The same hardware can be used for inspecting 18" pipes with minor modifications and for 8" pipes with a smaller GPR control box (currently not available).

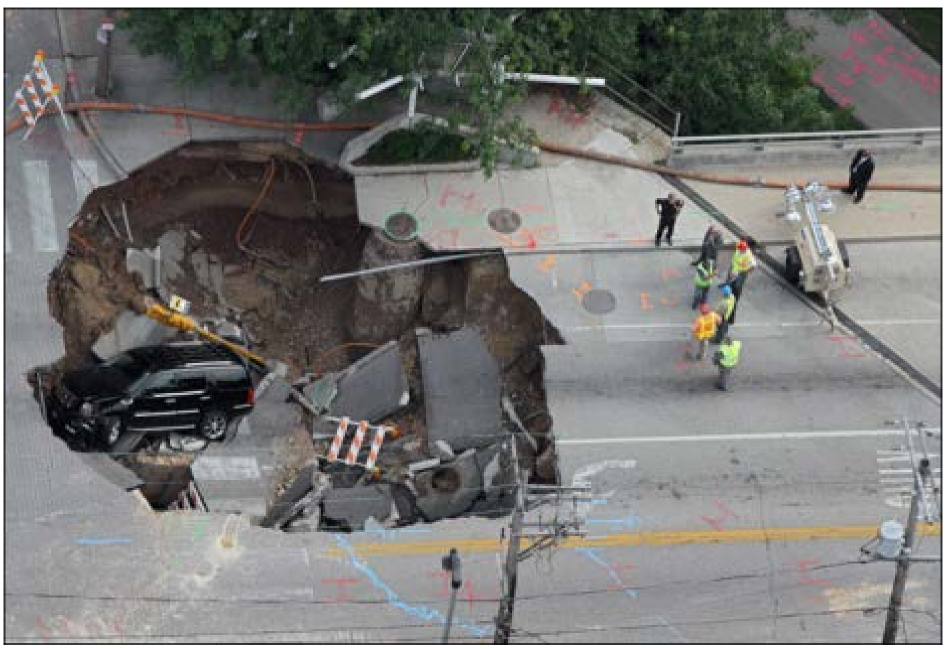
The motorized carrier mechanism used on the ACPS was a major technological breakthrough. The company had previously outsourced hardware design. Third party hardware, however, consistently failed. This project allowed the company to develop its own carry mechanism, that was 100% designed in house and is therefore, reliable, scalable, easy and inexpensive to repair and so far superbly functional. With this strong foundation a new chapter began in the history of the company and in the history of pipe condition assessment.

The project made a huge positive impact on the firm in terms of service and technology offering, opened up a new and potentially lucrative world-wide market and elevated the company to a whole new level.

Negotiations with consortium partners and service providers are underway for securing service and hardware purchase contracts.

Introduction

Asbestos Cement (AC) pipe was a popular choice of engineers for potable water, sanitary sewer, and storm drain pipelines during the 1940s, 50s, and 60s. AC pipe was touted for its light weight, ease of handling, and corrosion resistant properties. About 12 to 15 % of water mains in the water distribution systems of Canada and the US are AC pipes. In some utilities, as high as 85 % of their water mains are AC pipes (Hu, et. al, 2013). An estimated 1,014,000 km of AC pipe were installed in Canada and in the US (Von Aspern, 2009). Hundreds of thousands of miles of these AC pipe are beyond or are approaching the end of their 50 year design lives. The condition assessment and subsequent rehabilitation of AC pipe needs to be addressed immediately (Ambler, 2015).



Consequences of catastrophic pipe failure. A common occurrence due to the aging water and sewer infrastructure.

Alberta has approximately 9,512,000 m of Asbestos Cement pipe and failures are often daily events. Traditional CCTV, the most commonly used condition assessment method does not provide sufficient information to determine the remaining service life of these pipes, it does not provide accurate timelines for replacement, nor predict future failure. Water is being lost, and sewage is being leaked into the environment. There is no technology on the market to assess the condition of these critical assets.

The majority of AC pipes are near the end of their design life.

The opportunity is to develop a pipe inspection system to assess the condition of AC (and other non-ferrous) pipes. The SewerVUE AC Pipe Scanner is a recent development from SewerVUE Technology Corp. (SewerVUE) that deploys high frequency pipe penetrating radar (PPR) antennas inside AC pipes to directly measure wall thickness, map defects, and detect voids outside the pipe and thereby provide complete condition assessment of the pipe and its surroundings. While the company's pipe penetrating radar technology has been used on large diameter non-ferrous sewer and water pipes, adapting and deploying this technology in water mains presents a significant technical challenge.

A dedicated AC pipe scanner would be able to deploy from a standard opening into a live main, and report to the surface in real time via fiber optic tether. This tool would allow Infrastructure owners the ability to inexpensively and quantitatively assess the condition of their non-ferrous pipes in live water (or sewer) mains.

The technology in based on integrating PPR, the in-pipe application of ground penetrating radar (GPR) with CCTV on a mobile platform that is able to traverse up to 1500 m of small diameter (6"-18") pipe, transmitting and recording data in real time while maintaining optimal antenna to wall contact.

The PPR technology is currently proven and has been deployed in large diameter (>24") gravity sanitary sewer and water pipes. Several kilometers of large diameter sewer pipes have been surveyed to date. A prototype AC Pipe Scanner (ACPS) has been built and tested successfully in a live 10" AC sewer pipe in March 2016.

A new condition monitoring tool such as the ACPS would save municipalities millions of dollars in not repairing otherwise good pipes (an old pipe is not necessarily a bad pipe and a new pipe is not necessarily a good pipe). Identifying problem pipes would help eliminate water loss (save costs) and sanitary sewer overflows (environmental benefit).

The key technological challenge is whether high frequency (> 2.6 GHz) antennas provide sufficient resolution for thin pipe walls and if the data can resolve pipe failure modes. Technical risks include data communication over long distances (1500 m) and the design of a system that would fit through a 6" pipe. Antenna positioning and the tractor system will be of particular significance and is to be designed and tested. Writing a new communication software will remain a challenge.

In this project, SewerVUE will design and test the ACPS capable of measuring wall thickness, profiling cracks, and detecting voids. This will help infrastructure owner's better assess the quality of their existing infrastructure. By deploying reliable tools, water and waste water commissioners can proactively manage their infrastructure instead of responding to breaks and losses piecemeal. By proactively managing public infrastructure, not only are the environmental impacts of water loss and sewage overflow mitigated, but significant savings through intelligent rehabilitation options can be realized.

Since asbestos is a hazardous material by identifying problem AC pipes (and good ones as well) the hazards to public health due to exposure to asbestos can be significantly reduced.

Currently the amount spent on pipe investigations in the USA and Canada is $ 3.28 billion per year (Banthia, 2006, ASCE 2005). The main AC and concrete pipe market is seen as pipes in the size range of 6 in to over 16 in. This market comprises of 2,742,000 km of pipe (EPA, 2002). The EPA concluded that 10% of these pipes are in need of immediate repair. 15% of these are AC and 80% of these pipes are reinforced concrete (RCP). Therefore, the estimated total primary market size is $ 5.2 B. If only 10% of these pipes are inspected every year, then the total addressable market is $520 M/yr based on a conservative charge out rate of $12/m.

We believe that a city or municipality should be able to not only avoid catastrophic failures but also better manage their infrastructure inventory and reduce the costs and closures associated with water loss, emergency repairs, fines associated with sanitary sewer overflows (SSO) or replacing water and sewer mains by 25 to 40 % through the ability to do quick, accurate and non-destructive pipe inspections as a result of using our pipe inspection technology for an investment of approximately $12/m.

While many technologies, such as acoustic, electric and CCTV, exist to quantify the condition of steel, ductile iron, pre-stressed concrete cylinder (PCCP) etc. pipes, no technologies currently exist that can accurately quantify the remaining wall thickness and remaining service life of AC and other non-ferrous pipes. This added level of information is the missing link in accurately determining the correct replacement time of aging infrastructure and the correct rehabilitation option of problem infrastructure.

The savings would also include better cost allocations. Typically replacements costs are in the $300 -$900/m for rehabilitation and $600 -2400/m for replacement. At the estimated $12 -$24/ft inspection cost the savings are significant.

The technology has been proven for large diameter pipes (>24”). High frequency (2.6 GHz) antennas have been tested on pipe samples and provided sufficient resolution. An inexpensive and limited capability (“quick and dirty”) prototype has been developed and deployed in a 10” AC pipe.

TRL at the end of the project is a production ready prototype that can handle pipe sizes in the 6” to 18” range, together with the data collection, processing and reporting software. A critical asset at this point will be the collected and processed data to fine tune data interpretation.

TRL start of project: 4 **TRL end of project: 7**

Project Description

The objective of the project is to develop a reliable non-destructive testing method that can detect defects and cavities within and outside small diameter (6” - 18”) non-ferrous (AC, concrete, PVC, clay, etc.) underground pipes. The company has demonstrated feasibility of the concept through both robotic and manual data acquisition and analysis.

A secondary and equally challenging objective is to have the system operated by a technician with data analysis and reporting conducted subsequently at a remote location. Control and data collection is done remotely via fiber-optic cable and is recorded together with the output from CCTV. Subsequent data analysis via the new software will produce a user friendly report identifying and locating anomalies (defects or cavities) inside and outside the pipe wall.

Project Objectives (as defined in the Contribution Agreement)	Achievements Against Objectives
Scope: The objective of the Project is to develop a reliable non-destructive testing method that can detect defects and cavities within and outside small diameter (6” - 18”) non-ferrous (AC, concrete, PVC, clay, etc.) underground pipes.	A working prototype that works in the 10”-15” pipe diameter range, can handle gravity pipes, and can inspect 1000 m in a single run. Pilot projects were completed in Surrey, BC, deployment was completed in Taber, AB.
Technical: inspection distance 1000m. Void detection: 4”to 6”	Inspection distance 1000m. Void detection: 4”to 6”
Economic: cost to manufacture under CAD 175,000.	Cost to manufacture under CAD 175,000.

Phase 1: Design, Duration: 3 months

Project Objectives (as defined in the Contribution Agreement)	Achievements Against Objectives
Phase 1 Obtain high frequency antennas from IDS, modify electronics to fit in 8 inch pipes.	Completed Electronics fit in 8 inch straight pipes.
Test communication first over 1000 m then 1500 m copper tether, then test limits over fiber.	Completed
Conceptual design of carrier mechanism (pull through vs. ROV).	Completed
Source and test HD IP CCTV.	Completed
Determine if one or multiple antennas will be used.	Completed. One antenna
Solve antenna positioning.	Completed
Ph 1 deliverables Part specifications (antenna frequency, number of antennas, tether length, camera, number of cameras, on board storage vs. data communication through tether) finalized	Completed
Phase 2 Lab prototype. System for 8”-12” pipes (low hanging fruit), or go with single size option (i.e. dedicated hardware for each pipe size).	Completed
Design drawings for hardware.	Completed
Off the shelf or custom made components for mechanical parts?	Completed. Custom made components were chosen.
Data communication protocol.	Completed
Power supply over tether vs. batteries?	Completed. Over tether.
Begin design of Software Release 1.0 (SR. 1.0) of customized collection, processing and analysis software and construction of a defect data library. Develop a graphical display of raw PPR data coupled to dimensional and position information and CCTV recording.	Completed
A working prototype for a pull through system that works in 8”-12” gravity pipes, and can inspect at least 150 m in a single run.	Completed
Operational data collection software	Completed
Phase3 Assemble Production model and begin testing first in gravity sewers.	Completed
Testing of different clocking positions, increase the number of runs.	Completed
In situ data collection in a variety of pipes (storm	In situ data collection was collected in live

Project Objectives (as defined in the Contribution Agreement)	Achievements Against Objectives
sewer, sanitary sewer, water mains, etc.) with a variety of internal diameters and wall thicknesses. Test system in differing soils, hostile environments (H2S, debris, water flow, etc.) and levels of pipe degradation in lined and unlined pipes.	sanitary sewers. Once the robot had been in a sewer pipe water pipes were excluded from testing for water safety reasons.
Refine prototype robot control systems for clock positioning, sensor arms, data transmission and storage, obstacle avoidance and high density scans of small areas of interest.	Completed
Increase distance starting with 150 m	Completed
Gradually extend inspection distance to 1500 m	Partially Completed: the 1500 m tether had a 6 months lead time and the costs were well beyond the available budget.
Increase hardware range to include 6” and 15” to 18”	In progress: design was completed for 10-15” pipes, once smaller control box becomes available we will work on the 6-8” sizes
Test in pressurized water pipes.	Postponed: testing in any water pipe would require a new system for water safety reasons.
Progress software development to data processing and analysis. Utilise, coupons, exposed pipes, core samples and excavation to validate results. Merge PPR data with CCTV output and look for ways to prompt operator regarding identification of areas of interest. Continue to build library and defect analysis tools.	Data processing and analysis software is completed. Coupons and exposed pipes were not available during the project.
Milestones: A working prototype that works in the 6”-18” pipe diameter range and can handle both gravity and pressure pipes, and can inspect 1000 m in a single run.	A working prototype that works in 10” straight pipes or 12” and larger pipes with 90 degree bends, can handle gravity pipes, and can inspect 1000 m in a single run.
Identify pilot locations and pipes.	Completed
Operational data processing software for PPR and CCTV	Completed
Phase 4 Increase field test to include pressurized water mains over increasing distance, modify and fine tune hardware as required.	As explained above: testing in water pipes was not possible with the current hardware. Field testing and fine tuning of both hardware and software are ongoing.
Pilot projects	Surrey, BC pilot project completed. Taber, AB pilot project completed.
Finalise operator interface design. Complete Software R. 1.0. Library and data analysis algorithms must be sufficient for initial	Partially completed. Currently negotiating a service contract with BC municipalities.

Project Objectives (as defined in the Contribution Agreement)	Achievements Against Objectives
commercial contracts. Ongoing contract experience will be used to continue building analysis expertise and library for a wider range of defects and concrete/soil conditions.	
A field tested and production ready pipe inspection system prototype that can handle pipe sizes in the 6” to 18” range (gravity or pressure) up to 1500 m form a single entry point, together with the data collection, processing and reporting software. Work with consortium partners to deploy system on a pilot scale leading up to long term contracts and mass production	A prototype system that can handle pipe sizes in the 10” to 15” range (gravity) up to 1000 m form a single entry point, together with the data collection, processing and reporting software. Discussion with a consortium partner on a pilot project has started.
Functioning data collection, processing and reporting software developed and calibrated.	Completed

Not all the project plans were completed. In hindsight, the original project proposal/plan was highly ambitious. Completing all project tasks and plan would have required approximately two years, three times the team and budget. The company continues with the project albeit at a slower pace and with reduced personnel and budget.

However, critical milestones have been achieved and we are very close to a commercially viable end product.

Unexpected challenges and obstacles encountered during project execution:

Once the high frequency antennae were acquired from the Italian GPR manufacturer size limitations become obvious: the control box would not fit into pipes smaller than 8 inch. With the required connectors and water proof housing this meant a 10” minimum pipe size with no bends or 12” and larger pipes with 90 degree bends.

The motorized carrier mechanism was a major technological breakthrough. The company had previously outsourced hardware design. Third party hardware, however, consistently failed. Not one field project was completed without major robot breakdown that delayed project schedules, frustrated clients, increased deployment costs and significantly reduced profitability. No matter how many times the original, 3rd party robot was serviced and/or overhauled it always failed in the field. In contrast, the SewerVUE designed components (PPP, LiDAR, etc.) always worked. This project allowed the company to develop our own carry mechanism, that was 100% designed in house and is therefore, reliable, scalable, easy and inexpensive to repair and so far superbly functional. With this strong foundation a new chapter began in the history of the company and in the history of pipe condition assessment.

Despite a promising start and the contributions from the newly hired mechanical engineer (A. Korolev, PhD, PEng.,) parts from China were consistently delayed or not up to their own specifications. Since robotics is a precision business, these parts had to be manually re-machined at the time when local machine shops were already working at full capacity. This caused further delays and additional costs.

The rubber wheels had to be manufactured in house to meet project deadlines. Various materials were researched, ordered and tested until the right components were finally discovered. Even then due to the slow curing time only one wheel could be manufactured per day. Once the first 6 wheels were made they were put through the life cycle test. At the end of this test the rubber failed and the whole process had to be started again.

In order to extend the range of the robot beyond 3000 ft fiber-optic cables had to be employed. There are only 3 such cable manufacturers in North America. The specifications were not known until the power draw of the whole system could be calculated, that in turn required having all the components in-house. Since the cable manufacturers work with long lead times, even obtaining quotations required persistence and continued prodding. The cables were not only expensive but the lead times were also in the 3 to 6 months range. Chinese suppliers offered better prices and quicker turnaround but their English language and communications skills left much to desire. They also insisted on upfront payment via Western Union with no recourse if the goods were not up to specs or did not arrive at all.

A working prototype that was tested in sewers (sewer pipes are easy to access, since there are manholes roughly at every 150 m, and require minimum permitting and bureaucracy) could not be placed into a water pipe for obvious water safety reasons. A dedicated water system would require a duplicate of everything: robot, PPR antennae and control box, cameras, lights, tether, winch, etc. therefore, doubling hardware costs and the time to build. It is also not feasible to duplicate a system until all the issues and kinks had not been ironed out first.

Finally, there was also a significant (but very educational) learning curve on how to manage a complex engineering project. Prior to the project our expertise was limited to adding additional sensors to the existing third party robot (incremental change) which were relatively simple and straight forward, therefore, we did not have a robust design and review process in place. The earlier mentioned mechanical engineer who excelled in the first 6 months, seemed to have taken advantage of this and consistently ignored design suggestions and consistently missed deadlines, so that he was eventually laid off. Finding and onboarding a qualified mechanical engineer further delayed the project.

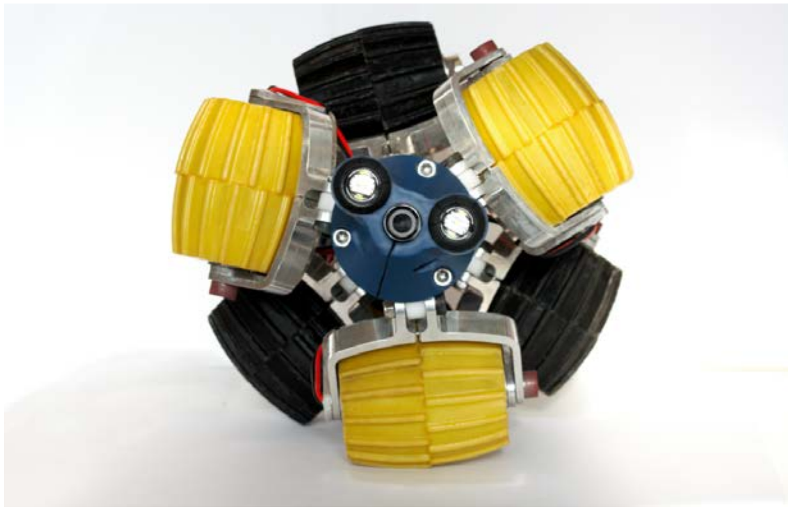
All these unforeseen challenges, delays and associated cost overruns resulted in reaching only minimum project objectives and partial completion of all the project tasks.

(In comparison, one of our competitors, with a much larger budget (USD 5M) and longer time frame (4 years) failed to produce even a working prototype.)

Data collection and processing software has been completed, field tests in a Surrey, BC and later in an Alberta pipe were completed on February 26, 2019.

Results and Outcomes

One ACPS prototype has been produced.



Front view of the ACPS prototype.

Results of lab and pilot tests as appropriate. How did the technology perform?

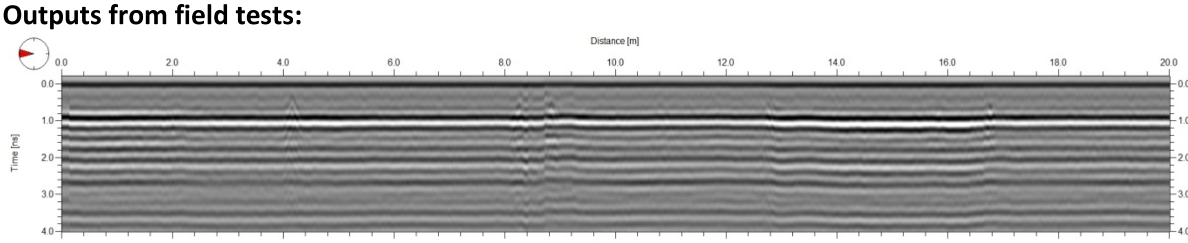
Photos from one of the Surrey, BC in pipe tests showing the inspection truck and robot on site (left) and robot being inserted into the pipe (right).

Taber, AB field test showing manhole location, inspection van and municipal support vehicles.

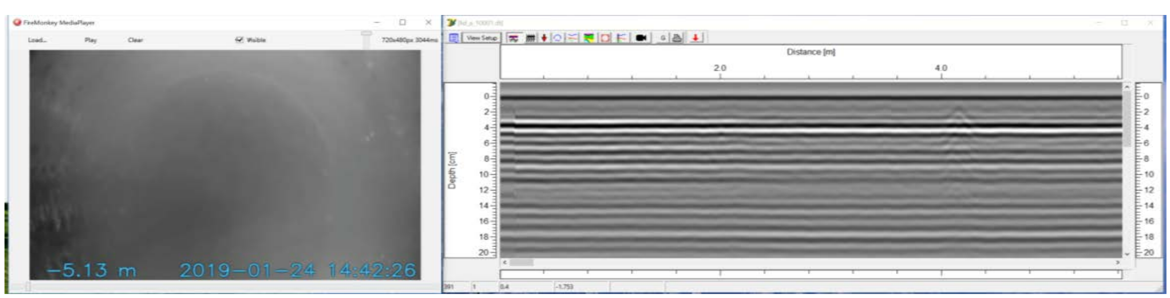
ACPS robot and field crew before deployment in Taber, AB.

ACPS robot prior deployment (left) and being inserted into manhole (right).

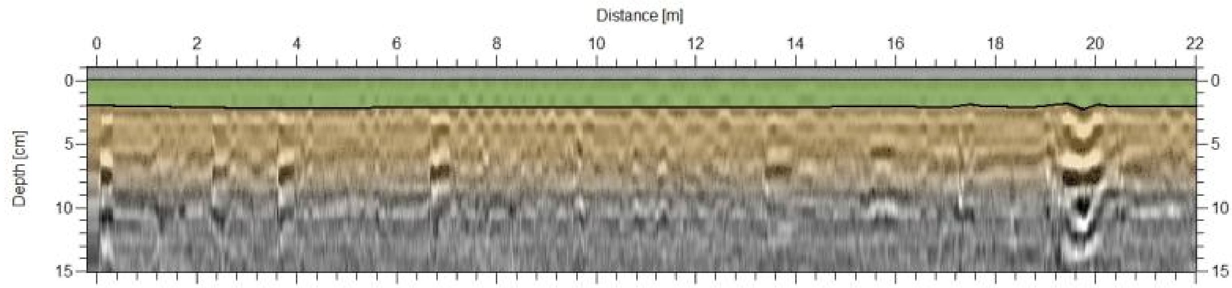
Outputs from field tests:



ACPS sample output showing consistent wall thickness (1 ns depth) and pipe joints at every 4.2 metres.



ACPS sample output showing synchronized CCTV (left) and PPR results (right). Anomaly (faint hyperbola) on the PPR profile at 4.15 m is likely a separated joint that is not picked up by CCTV.



ACPS “classic view” (where interpretation is superimposed on the processed PPR profile) sample output showing 2 cm wall thickness from a 10” AC pipe. Anomalies at 19.8 m show irregularities in pipe bedding.

Analysis and discussion of results

The prototype robot performed well in the field trials. Further testing is needed understand the shortcomings, however, the current version is well suited for commercial operations.

Following the satisfactory pilot tests the company has initiated discussions with current consortium partners (City of Surrey, BC) for implementing a commercial rollout as a service. A proposal is being prepared to be submitted in mid March 2019. If accepted, the service contract could start in May 2019.

The company has received interest from a European service provider and is negotiating the first European pilot, tentatively scheduled for Summer 2019. The interested party expressed a strong desire to purchase equipment following a successful pilot.

Metric	Ideal target	Minimum requirement	Achievements to date
Inspectable minimum pipe size	6” to 18”	8” to 15”	10”to 15”
Inspection distance	1500 m	1000 m	1000 m
Inspect pressurized pipe	Pressurized water pipe under normal operating conditions	Gravity sewers under low flow conditions	Gravity sewers under low flow conditions
Efficiency to detect cavities	2” – 4”	4” to 6”	4” to 6”
Target cost to manufacture	Under CA $ 125,000	Under CA $175,000	Under CA $175,000

Description of successes and failures as well as important lessons learned

Lessons learned: people are people and their performance has to be rigorously monitored. “Give them directions and the tools and get out of the way” does not work with everyone.

Third party equipment is critical in this kind of project and a good working relationship is essential with the third party. This, however, is costly and time consuming, but, still the best course of action compared to building everything in house.

Failures always come down to the basics: lack of money, lack of time and lack of talent, however, we consider these temporary roadblocks. They generate new knowledge and form the basis of the next technological achievement.

Relevance and Benefits

According to the 2011 Statistics Canada report on Municipal water use, there's an estimated 13.3% water loss per capita in Alberta. The average estimated water loss in North American networks is about 20 per cent, most of this being leakage (Brothers, 2001). Globally, most countries fall into the range of 20-30 per cent (Lai, 1991).

The Canada Municipal Water Report notes water waste to as much as doubles from small cities of under 1000 people to large cities of over 500 000. As the number of cities in Canada above the 500 000 population mark increase, the water waste will cost much more should Provinces continue to use the available and incomplete technology to assess their water systems.

Despite improvements in household water conservation, Canada remains one of the largest per capita users of fresh water in the world. Managing water demand, and the financing of building and repairing water infrastructure, are a priority for many communities. Managing water use helps prevent a wide variety of environmental and economic problems, including water shortages, increased concentration of pollutants in water bodies, costly expansion of water and wastewater infrastructure, and increased energy consumption to pump and treat.

Assuming 510 litre used per capita per day (2009 Municipal Water Use Report), and a 2004 population of 4.146 M, Alberta is losing close to 281 M litres of water daily. According to the Alberta Energy Regulators 2013 Pipeline performance report, approximately 21.3% of Alberta's pipeline infrastructure is non-ferrous, and 41.7% (10,932 Km) of the total inventory (24473 Km) is >4" in diameter. Though some pipe materials are more susceptible to certain failure modes, such as internal corrosion, it's sufficient to assume that of the 281 M litres of water lost per day in Alberta, roughly 117 M litres is a result of non-ferrous breaks. Of this 117 M, 49 M litres are lost due to non-ferrous pipe failures in pipes greater than 4 inches in diameter.

While we have seen significant decreases in the number of pipe failures since the 90's (AER 2013B), it is clear that current technologies have plateaued in their ability to provide the information needed to develop effective preventative maintenance programs. It's estimated that the AC Pipe scanner could survey 4 km of pipe per day. With 10,932 km of target pipe in Alberta, and 10 AC Pipe Scanner systems, one could scan all of Alberta in just 275 working days. Provided the AC Pipe Scanner could reduce just

10% of the total water loss, Alberta could save upwards of 5 M litres of water per day or 1.8 Billion litres of water per year.

The majority of the environmental impact of the AC Pipe Scanner System will be seen in through the reduction of water loss, elaborated in the previous section.

Additional benefits will be seen in the wastewater conveyance system. The majority (91%) of sanitary pipes in Canada are ≤ 24 " in diameter, with non-ferrous pipes making up over 83% of the inventory. VC being the most common material overall at 35% of total pipe length, followed by CO at 25% and PVC at 23%, then finally AC at 12%.

Due to the limitations of the existing technologies mentioned elsewhere in this proposal the condition of these assets are not well known. Exfiltration rates have been reported to be between 1% and 13% of downward flow and the impact that has on groundwater varies by region. By better condition assessment exfiltration can be reduced providing further environmental benefits.

Since asbestos is a hazardous material by identifying problem AC pipes (and good ones as well) the hazards to public health due to exposure to asbestos can be significantly reduced.

By providing an economically viable technique for measuring the condition of AC pipes municipalities and pipe owners can make intelligent decisions regarding the remaining service life of their pipeline infrastructure. With replacement and rehabilitation costs often in the millions of dollars, intelligent deferral can introduce significant savings on the downstream end. On the other hand, developing sinkholes detected with the technology can be repaired before causing catastrophic failures and significant economic loss.

Competitors, such as traditional CCTV or leak detection systems only provide a qualitative report of the pipe condition. With SewerVUE's proposed solution, pipe condition can be quantified, and areas where re-habilitation is needed pinpointed; cutting out the guesswork of fixing otherwise good pipes or unnecessarily replacing pipes which still had a long service life.

While the largest economic impact of our system comes from the millions saved through intelligent preventative maintenance, there is also revenue impact through the form of manufacturing, sales and export.

Market Roll-out Table (summary)

Year	Alberta			Rest of Canada			Rest of World		
	Forecast (Units)	Unit Price	Revenues ($)	Forecast (Units)	Unit Price	Revenues ($)	Forecast (Units)	Unit Price	Revenues ($)
2020	1	400,000	400,000	1	400,000	400,000	1	400,000	400,000
2021	2	400,000	800,000	2	400,000	800,000	2	400,000	800,000
2022	8	400,000	3,200,000	8	400,000	3,200,000	8	400,000	3,200,000
2023	8	400,000	3,200,000	14	400,000	5,600,000	14	400,000	5,600,000
2024	8	400,000	3,200,000	22	400,000	8,800,000	22	400,000	8,800,000
2025	9	400,000	3,600,000	28	400,000	11,200,000	28	400,000	11,200,000
2026	9	400,000	3,600,000	34	400,000	13,600,000	34	400,000	13,600,000
2027	9	400,000	3,600,000	40	400,000	16,000,000	40	400,000	16,000,000
2028	10	400,000	4,000,000	40	400,000	16,000,000	46	400,000	18,400,000
2029	10	400,000	4,000,000	40	400,000	16,000,000	52	400,000	20,800,000
2030	10	400,000	4,000,000	50	400,000	20,000,000	58	400,000	23,200,000

The project results may inform a provincial strategy, policy, regulation or operational practice with regards to the inspection and rehabilitation of AC pipes. The results have not yet been shared with the relevant body.

Job Creation Table

Total Number of Eligible Recipient's (ER) Full Time Equivalent (FTE) Employees and/or contractors working at Project Start	5
Number of ER's FTE Employees and/or contractors working **on the AI-SDTC Project (including staffing related to marketing and commercialization of the technology)** at Project Start	6
Final number of ER's FTE Employees and/or contractors	7
Final number of ER's FTE Employees and/or contractors working **on the AI-SDTC Project (including staffing related to marketing and commercialization of the technology)**	8
Net number of new FTEs AI-SDTC funding has created since Project inception	3
Approximately how many FTE employees and/or contractors do you expect to hire **(related to the AI-SDTC Project (including staffing related to marketing and commercialization of the technology)** in the next 24 months?	4

Overall Conclusions

Where was the technology at the start of the project and where is it now?

It was at TRL 4

It is now at TRL 7.

The project made a huge positive impact on the firm in terms of service and technology offering, opened up a new and potentially lucrative world-wide market and elevated the company to a whole new level.

Experience with Funders and how they have helped achieve our goals.

Please see above paragraph for the major positive outcomes, these would not have been possible without the funders' financial contribution.

Brett Purdy of Alberta Innovates was very helpful and approachable at every phase of the project. Working with him was remarkably easy and pleasant. This made project management and reporting very efficient. The company wishes to express gratitude to Brett for this and his other efforts in realizing the success of this project.

On the other hand, the funders don't seem to appreciate that a small enterprise lives (or dies) by cash flow, and how much cash flow strain and stress was created by payment delays at every milestone.

Communications Plan

The hiring of new marketing and sales personnel is in the works in order to initiate and maintain communicating information about the project, project findings, and results and the underlying technology/knowledge with key stakeholders and third parties.

Scientific Achievements

Presentations given at scientific meetings, public events and media appearances

Ékes, Csaba. "Application of Pipe Penetrating Radar for Asbestos Cement Pipe Condition Assessment." *Pipelines 2018.* Toronto: ASCE, 2018.

Ékes, Csaba. "The Application of Pipe Penetrating Radar in Asbestos Cement Water Pipes." *BCWWA Annual Conference 2018.* Penticton: BCWWA, 2018.

Publications

<u>Published:</u>

Ékes, Csaba. "Application of Pipe Penetrating Radar for Asbestos Cement Pipe Condition Assessment." *Pipelines 2018.* Toronto: ASCE, 2018.

<u>Draft:</u>

Ékes, Csaba. "Asset Management for Non-ferrous Pipelines Using Predictive Models." *UCT 2019.* Fort Worth: UCT, 2019.

Ékes, Csaba. "Pipe Penetrating Radar: Developing Predictive Models for Effective Asset Management." *WWETT 2019.* Indianapolis: WWETT, 2019.

Highly Qualified Personnel being trained as part of the project

Name	Organization	Level	Period	Thesis Title/Project	Status
Jiri Vejvoda	SewerVUE		1 year		In Progress
Igor Bragilevsky	SewerVUE		1 year		In Progress
Mackenzie Peatch	SewerVUE		1 year		In Progress

Other Highly Qualified Personnel

Csaba Ékes, Ph.D., P.Geo. - *President, Team Leader*

Boriszlav Neducza, M.Sc. – *CTO*

Nicholas Goertz, B.Sc. – *VP, Sales & Marketing*

Peter Takacs, M.Sc. – *Project Engineer*

Alexander Radcliffe, B.Sc. – *Project Engineer*

Zsolt Pellei – *Project Technician*

Gyorgy Rozmer – *Project Technician*