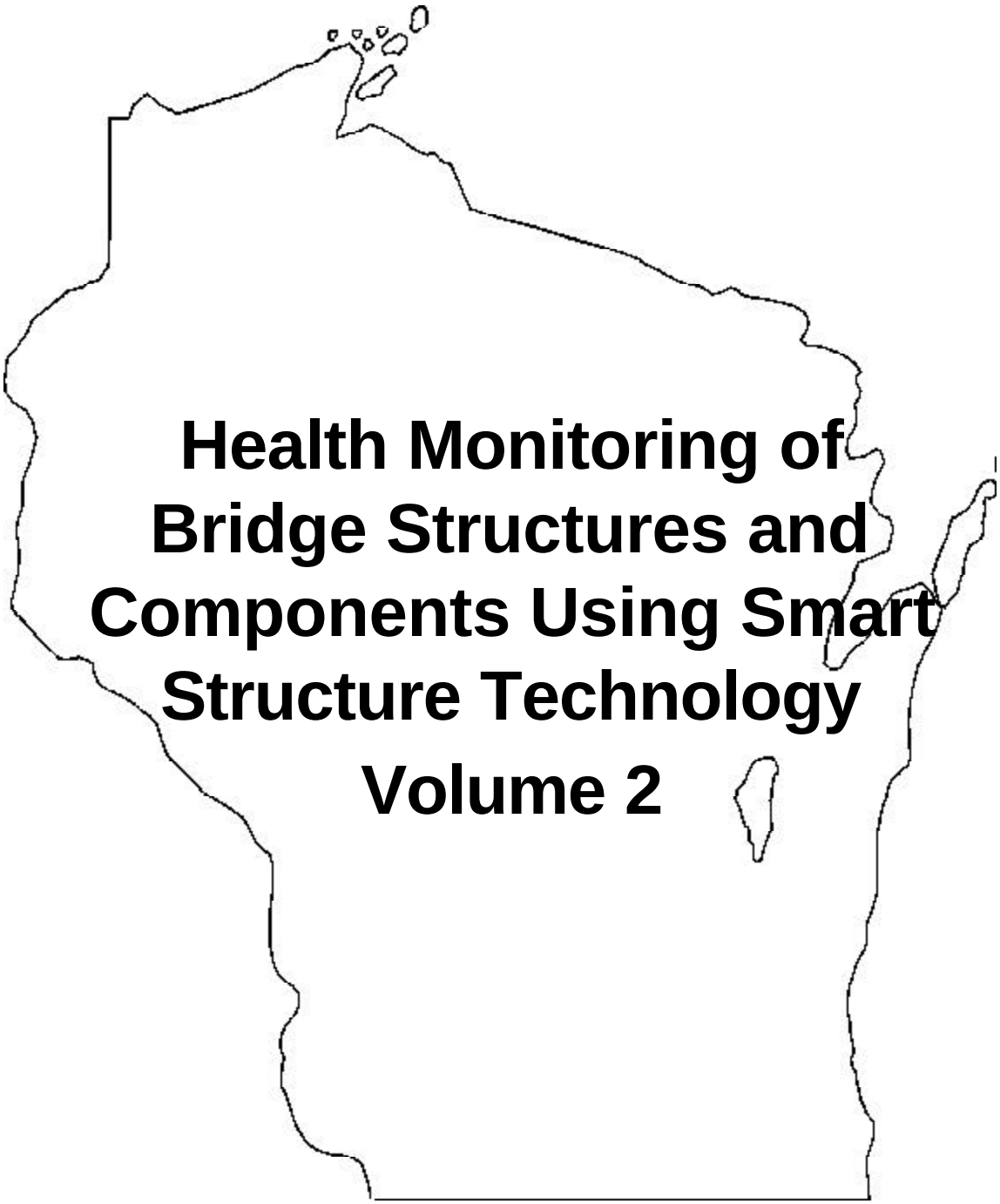
Wisconsin Highway Research Program



Health Monitoring of Bridge Structures and Components Using Smart Structure Technology Volume 2

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16. Abstract The objective of this research was to synthesize information on structural health monitoring technologies with a specific interest in those having smart-structure attributes. Following a comprehensive information collection campaign and a survey of State Departments of Transportation, the identified structural health monitoring technologies (both currently in use and emerging) were carefully reviewed and summarized. This final report includes a brief summary of the history of bridge evaluation in the United States of America, current and future trends of Structural Health Monitoring, and a series of completed *SHM Technology Evaluation Forms* for each of the identified technologies. In addition, a searchable database has been developed and is included with the final report that allows easy identification and review of structural health monitoring technologies. Volume I summarizes the research approach and the key findings of the work. This volume (Volume II) consists of completed *SHM Technology Evaluation Forms* for the 101 synthesized technologies.			
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EXECUTIVE SUMMARY

Project Summary

The objective of this research was to synthesize information on advanced structural health monitoring technologies with a specific interest in those having smart-structure attributes. Following a comprehensive information collection campaign and a survey of State Departments of Transportation, the identified SHM technologies (both currently in use and emerging) were carefully reviewed and summarized. The product of this work includes this report (Volumes I and II) and a searchable database of the individual technologies that have been synthesized.

Background

The ability to monitor the condition of a bridge structure to detect damage or changes in condition at early stages is of significant interest to many bridge owners. Currently, the most widely used damage detection methods rely on subjective, incremental visual assessments or localized testing techniques such as eddy current, ultrasonics, acoustic based sensing, strain monitoring, corrosion monitoring, and others. These methods require the location, or possible location, of damage to be known prior to the assessment. Often these locations can be estimated through appropriate engineering analysis. However, with the increasing complexity of many of the nation's bridges, potential damage locations may not be known or are too numerous to be economically tested using conventional techniques. Further complicating the issue is the fact that many conventional damage detection techniques do not allow for systematic comparison of the assessment results. Consequently, damage or deterioration cannot be easily monitored or tracked over time.

There are two primary approaches to health monitoring. First, install and monitor a relatively small number of sensors to monitor how the system is generally performing. Second, install and monitor a sufficient number of sensors with the application of advanced statistical analysis (or other methods) to detect and/or assess specific damage locations. Both approaches require various numbers of sensors and sensor types. The first provides specific behavior data, but may not reveal that important changes are taking place. This approach is well suited for an application where analysis indicates the possibility for a catastrophic failure is statistically low or in applications where the "cost" of a failure is acceptably low. For situations where specific damage or deficiencies are of significant importance or the "cost" of failure is high, one must follow the second approach, which requires the collection of significantly more performance information.

In the recent past, there have been rapid advances in the development of technologies for the evaluation of bridges. Advanced structural health monitoring has fast become a growing field in which non-intrusive damage detection techniques are integrated into a structure to monitor the complete bridge or individual bridge members. If properly implemented, it is believed that these technologies extend the useful life of bridges by allowing deterioration/damage to be identified earlier and thereby allowing relatively minor corrective actions to be taken before the deterioration/damage grows to a state where major actions are required. In addition, structural health monitoring systems allow designers to learn from previous designs to improve the performance of future bridges. While a number of structural health monitoring technologies exist, a thorough compilation of these various technologies does not. Such a synthesis of available information would allow bridge owners to more effectively select and apply these technologies.

The Iowa State University Bridge Engineering Center, through the Wisconsin Highway Research Program, conducted the project. The Research Team included Brent M. Phares (Co-principle investigator), Terry J. Wipf (Co-principle investigator), Lowell F. Greimann (Co-principle investigator), and Yoon-Si Lee (Research Assistant). The Project Oversight Committee included Thomas Strock (Federal Highway Administration), Chris Foley (Marquette University), and Joel Alsum (Wisconsin Department of Transportation).

Process

The research consisted of four distinct work tasks. The first task, Task I, involved identifying the information that must be gathered to not only effectively monitor a bridge structure but to also be able to select an appropriate monitoring approach and technology. The product of Task I was a *SHM Technology Evaluation Form* that would be used in the synthesis of the identified structural health monitoring technologies. The intent was that the completed forms would provide a brief summary of the capability and applicability of each technology. Task II focused on collecting information on structural health monitoring technologies that are currently being used either successfully or with limited success. Similarly, Task III focused on identifying and evaluating technologies that are not currently being applied within the bridge engineering community but have potential applications. To collect information, a survey of State Bridge Engineers was performed and numerous technical reports and other literature were reviewed in addition to directly contacting numerous manufacturers. Task IV was accomplished by summarizing and synthesizing the collected information. The process for evaluating the applicability, capability, and viability of continuous or advanced health monitoring sensors and techniques, which is included in the completed *SHM Technology Evaluation Forms*, was based on unbiased, qualitative assessments of the ability of each technology to measure the metrics defined during Task I.

Findings and Conclusions

The product of this work includes a brief summary of bridge evaluation history, current and future trends of structural health monitoring technologies and a series of completed *SHM Technology Evaluation Forms* for each of the synthesized technologies. A comprehensive database was also developed to allow easy identification and review of structural health monitoring technologies and to facilitate the selection of technologies for a specific application. With this database, the user can prescribe a specific set of parameters (e.g., type of bridge, element type, etc.) for which they would like information on available monitoring technologies; applicable technologies are then automatically identified.

Although there are several technologies with "*Smart*" attributes, the research team was able to identify only one SHM system that satisfied the definition of "*Smart*" used in this work. This system, manufactured by Pure Technologies, utilizes sensed information to determine if a wire break has occurred in either a prestressed concrete structure or a cable-supported structure. Several SHM systems classified at "*Smart*" by the developers are currently in the development stages. However, it is unclear if these systems will, indeed, possess all of the characteristics to be considered truly "*Smart*."

LIST OF COMPANIES/INSTITUTES/ORGANIZATIONS

1. General Information

Description of Technology	SMART Layer, SMART Suitcase, ACESS Software Suite (built-in structural diagnostic system for on-site/remote data collection and analysis): designed to be easily integrated into new or existing structures to automate inspection and maintenance procedures.		
Manufacturer and Contact information	Acellent Technologies, Inc. 155C-3 Moffett Park Dr. Sunnyvale, CA 94089	www.acellent.com Tel: (408) 745-1188 Fax: (408) 745-6168	
Features	Sensor type	SMART Layer (built-in sensor network for area sensing): a thin dielectric film with an embedded network of distributed piesoelectric actuators/sensors; it can be manufactured in a variety of sizes, shapes, and complexity.	
	Data acquisition, processing, and archiving	SMART Suitcase (Model SCS3100/3200 and others): a portable signal generation and data acquisition instrument, 12 bit high-speed data acquisition board. ACESS Software: provides utilities for signal processing and data visualization, data management tools and other.	
	Communications	Direct wire connection. System can also be remotely controled through ethernet or internet (remote control software is needed for this function).	
	'Smart' attributes	Autonomous inspection and maintenance procedures (structural condition monitoring, damage detection, process monitoring, etc.).	
	Other	SMART Suitcase is compatible with other sensors (developed by a third-party company) in multi-channel data acquisition.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☒ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☐ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☒ Main/secondary cable ☒ Cable anchorage ☒ Anchor rod ☒ Damping system ☒ Strand shoes ☒ Cable bands ☒ Cable enclosures ☐ Other: 2. Movable bridge ☒ Electric brakes ☒ Motors and power ☒ Operating machinery and equipment ☐ Other:					
	Other: Any critical, high stress areas (joints, etc.).					

Monitoring Interest

☒ Crack/fracture	☒ Expansion/contraction	☒ Rotation/torsion	☒ Wear/spalling/scaling/delamination
☒ Section loss	☐ Settlement	☐ Misalignment	☒ Connection failure or deficiencies
☒ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☒ Impact damage
☒ Debonding	☐ Erosion/scour	☐ Looseness and pounding	☐ Excessive joint closing/opening
☐ Corrosion	☐ Environmental	☐ Other:	

Measurement Metric

☐ Strain	☐ Deflection/displacement	☐ Acceleration/vibration	☐ Moisture/humidity level
☐ Temperature	☐ Magnetic field/flux	☒ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☐ Other:	

3. Cost		
Hardware	Sensor	Standard 8-sensor SMART Layer: $500~$2,000.
	Data acquisition system	64-channel system: $7,500~ (other systems available).
	Communication system	
	Data archiving system	
	Other	Laptop (for remotely controlling the system): $2,000 (optional).
Software	$2,500~$15,000.	
Labor	Installation	
	Use	
Other: Custom design is normally priced higher depending on numbers of sensors employed.		

4. Limitations	
Life expectancy	No official life expectancy. Additional protective coating over sensors can be applied for longevity.
Power	110/220V AC.
Environmental conditions	SMART Layer: -40°C to 90°C. SMART Suitcase: 0 to 45°C.
Data storage/transfer/ processing	Output frequency: 61 mHz to 10 MHz. Sampling rate: 5 MS/s, 10 MS/s and 25 MS/s at dual-channel mode.
Other:	

5. Implementation Needs	
Power source	Normally any available ground-line power supply or generator. AC/DC.
Accessibility	Direct access needed for sensor installation and data acquisition (remote control system optional).
Technical expertise	Moderate training on how to operate the system.
Other: Intell Pentium III processor. Microsoft Windows 2000 Pro or newer version.	

6. Availability

Upon agreement.

7. On-Going or Completed Bridge Related Projects and References

No bridge related projects yet; manufacture claims that the system is well suitable for bridge structures.

References:

- Lin, M. "Development of SMART Layer for Built-in Structural Diagnostics," Structural Health Monitoring 2000, Stanford University, Palo Alto, California, pp. 603-611, 2000.
- Lin, M., Qing, X., Kumar, A., and Beard, S.J. "SMART Layer and SMART Suitcase for Structural Health Monitoring Applications," Acellent Technologies, Inc.

8. Notes

- Acellent Technologies, Inc. was founded in 1999 to enhance development and commercialize the smart structures technology emerging from Stanford University's research labs; the company develops and manufactures sensor network products that leverage its proprietary SMART Systems technologies to obtain solutions for real-time structural health monitoring.
- Additional feasure of the system: robust hardwire connections wire 30 sensors directly to the SMART Suitcase; SMART Layer can incorporate other types of sensors to monitor properties such as strain and moisture; sensors can either be surface-mounted on existing structures or integrated into new structures during fabrication or construction; real-time structural health monitoring of a wide-range of damage critical structures or components.
- Impact detection system also available: users can utilize the system continuously in real-time to detect external impact events, time of impact, location of impact, impact energy/force, severity of impact (together with active system).
- Acellent's products are available in standard or custom design configurations.
- Use of the system on concrete structure seems questionable; it is possible but the sensor was designed mainly for composite and steel structures.

1. General Information

Description of Technology	Corrosion monitoring system with ACM concrete probe.	
Manufacturer and Contact information	Advanced Corrosion Monitoring (ACM) Instruments 125 Station Road, Cark, Grange-over-Sands LA11 7NY, England	www.potentiostat.com Tel: +44 (0)15395 59185 Fax: +44 (0)15395 58562
Features	Sensor type	Monitoring embeddable probes, each probe with 8 electrodes.
	Data acquisition, processing, and archiving	Concrete 32 (built originally for monitoring bridge decks): a matrix switching arrangement at the front of each of the 32 channels allows any combination of 8 embedded probes per channel to be monitored for galvanic currents, LPR and potential. Temperature is measured and the instrument can accept ER probes. The resulting data is then plotted as a 2D or 3D contour map to help with bridge repair and operation.
	Communications	Direct wire connection. Remote control and monitoring via phone or internet is also available.
	'Smart' attributes	Capable of generating 2D and 3D corrosion contour map to help with bridge repair and operation. Alarming system for high corrosion.
	Other	Field Machine: corrosion monitoring and data acquisition device for concrete structures (available from single channel to 12 channels).

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☐ Timber:	☐ Plank ☐ Nailed laminated ☐ Glue-laminated ☐ Prestressed laminated ☐ Stressed timber ☐ Other:
	☒ Concrete:	☒ Reinforced ☒ Prestressed/post-tensioned ☐ Other:
	☐ Steel:	☐ Grid ☐ Orthotropic ☐ Buckle plate ☐ Corrugated steel flooring ☐ Other:
	☐ FRP:	
Superstructure	*Primary Element*	☒ Multi-beam/girder system: ☒ Girder floor beam/diaphragm system ☒ Tee beam ☒ Box girder ☒ Channel beam ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:
	Secondary Element	☐ Connector and fastener: ☐ Riveted/bolted ☐ Welded ☐ Pin & hanger ☐ Splice ☐ Bracing: ☐ Cross ☐ Lateral ☐ Sway ☐ Diaphragm ☐ Cover plate ☐ Stiffener ☐ Other:
	Bearing	☐ Fixed ☐ Expansion: ☐ Sliding plate ☐ Roller ☐ Rocker ☐ Pin and link ☐ Elastomeric ☐ Pot ☐ Restraining ☐ Other:
	Other:	
Substructure	☒ Abutment:	☒ Footing ☐ Bridge seat ☐ Piles ☒ Wall (stem/back/wing) ☐ Other:
	☒ Pier/bent/extended pile:	☒ Pier cap ☒ Shaft ☒ Column/stem ☐ Submerged pile/pile cap/footing ☐ Other:
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)*	1. Cable-supported bridge ☒ Tower ☐ Main/secondary cable ☐ Cable anchorage ☐ Anchor rod ☐ Damping system ☐ Strand shoes ☐ Cable bands ☐ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:
	Other:	

Monitoring Interest

☐ Crack/fracture ☐ Expansion/contraction ☐ Rotation/torsion ☐ Wear/spalling/scaling/delamination
☐ Section loss ☐ Settlement ☐ Misalignment ☐ Connection failure or deficiencies
☐ Deformation ☐ Wire breakage ☐ Mechanical/electrical malfunction ☐ Impact damage
☐ Debonding ☐ Erosion/scour ☐ Looseness and pounding ☐ Excessive joint closing/opening
☒ Corrosion ☐ Environmental ☐ Other:

Measurement Metric

☐ Strain ☐ Deflection/displacement ☐ Acceleration/vibration ☒ Moisture/humidity level
☐ Temperature ☐ Magnetic field/flux ☒ Electrical voltage/current ☒ Chemical composition
☐ Radar waves ☐ Acoustic waves ☐ Magnetic waves ☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☐ Wind speed/direction ☐ Other:

3. Cost		
Hardware	Sensor	
	Data acquisition system	Field Machine: $20,020 for single channel ($1.00 = £1.82).
	Communication system	
	Data archiving system	
	Other	
Software		
Labor	Installation	
	Use	
Other: Cost of typical monitoring system ranging from $8,000 to $60,000 depending on the size of project. Cost can rise if high-technology (remote communication, additional software to report high corrosion alarms, etc.).		

4. Limitations	
Life expectancy	15 years plus. Up to 5 year-warranty.
Power	110/230V AC 50-60 Hz, or12V input/12V output for portable computer.
Environmental conditions	Operating temperature: -5°C to 72°C.
Data storage/transfer/ processing	Current output: +500 mA. Frequency response: 30 KHz (1 to 100k Ohm load). Frequency Range: 10 µHz to 30 KHz. Measurement resolution: 1 µV ± 0.0015% nonlinearity.
Other:	

5. Implementation Needs	
Power source	AC/DC, solar pannel.
Accessibility	Direct access needed for sensor installation and data acquisition (remote control system optional).
Technical expertise	Minimal training on how to operate the system.
Other: Operating system requirement: Windows 95, 98, ME, 2000 or XP (XP recommended for improved reliability). Minimum PC requirements- Standard PC with free serial port, Pentium 100, 64 MB RAM, 40 MB free disc space, CD Rom drive.	

6. Availability

Approximately 4 to 6 weeks.

7. On-Going or Completed Bridge Related Projects and References

Many corrosion monitoring projects on reinforced concrete structures in many countries (detailed information not available).

8. Notes

- ACM has been developing and supplying various corrosion monitoring instrumentations (both standard and custom design) since 1985.
- Custom elements, especially logging techniques can be created to bridge owner's specification; ACM often build a PC into their instrument (separately screened naturally); By adding internet connection either via a LAN, phone line or mobile phone, ACM offers new internet control software that the data can be retrieved from any PC connected to the internet, proving the ability to change parameters in the office.
- Other corrosion monitoring related products are also available.
- ACM does not seem to have that many experiences with bridge structures, but appears to have several engineers and people with plenty experiences of corrosion monitoring; the company claims that they can build any system to meet customer's needs.

1. General Information

Description of Technology	Laser displacement measurement sensor technology.		
Manufacturer and Contact information	Acuity Research Inc. 10624 S. Eastern Ave., Suite A-271, Henderson, NV 89052	www.acuityresearch.com Tel: (702) 616-6070 Fax: (702) 616-6071	
Features	Sensor type	Laser displacement sensors: AR200 is capable of measuring from 0.24 inches (6mm) to 1.97 inches (50mm) with up to 12 micron accuracy; AR600 from 0.125 inches (0.3cm) to 50 inches (128cm); AR4000 from 1.5 to 54 ft with an accuracy of 0.1 inches.	
	Data acquisition, processing, and archiving		
	Communications		
	'Smart' attributes		
	Other		

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☐ Timber: ☐ Plank ☐ Nailed laminated ☐ Glue-laminated ☐ Prestressed laminated ☐ Stressed timber ☐ Other:	
	☐ Concrete: ☐ Reinforced ☐ Prestressed/post-tensioned ☐ Other:	
	☐ Steel: ☐ Grid ☐ Orthotropic ☐ Buckle plate ☐ Corrugated steel flooring ☐ Other:	
	☐ FRP:	
Superstructure	*Primary Element* ☐ Multi-beam/girder system: ☐ Girder floor beam/diaphragm system ☐ Tee beam ☐ Box girder ☐ Channel beam ☐ Slab ☐ Truss member ☐ Arch element ☐ Other:	
	Secondary Element ☐ Connector and fastener: ☐ Riveted/bolted ☐ Welded ☐ Pin & hanger ☐ Splice ☐ Bracing: ☐ Cross ☐ Lateral ☐ Sway ☐ Diaphragm ☐ Cover plate ☐ Stiffener ☐ Other:	
	Bearing ☐ Fixed ☐ Expansion: ☐ Sliding plate ☐ Roller ☐ Rocker ☐ Pin and link ☐ Elastomeric ☐ Pot ☐ Restraining ☐ Other:	
	Other:	
Substructure	☐ Abutment: ☐ Footing ☐ Bridge seat ☐ Piles ☐ Wall (stem/back/wing) ☐ Other:	
	☐ Pier/bent/extended pile: ☐ Pier cap ☐ Shaft ☐ Column/stem ☐ Submerged pile/pile cap/footing ☐ Other:	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☐ Tower ☐ Main/secondary cable ☐ Cable anchorage ☐ Anchor rod ☐ Damping system ☐ Strand shoes ☐ Cable bands ☐ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:	
	Other:	

Monitoring Interest

☐ Crack/fracture ☐ Expansion/contraction ☐ Rotation/torsion ☐ Wear/spalling/scaling/delamination
☐ Section loss ☐ Settlement ☐ Misalignment ☐ Connection failure or deficiencies
☐ Deformation ☐ Wire breakage ☐ Mechanical/electrical malfunction ☐ Impact damage
☐ Debonding ☐ Erosion/scour ☐ Looseness and pounding ☐ Excessive joint closing/opening
☐ Corrosion ☐ Environmental ☐ Other:

Measurement Metric

☐ Strain ☒ Deflection/displacement ☐ Acceleration/vibration ☐ Moisture/humidity level
☐ Temperature ☐ Magnetic field/flux ☐ Electrical voltage/current ☐ Chemical composition
☐ Radar waves ☐ Acoustic waves ☐ Magnetic waves ☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☐ Wind speed/direction ☐ Other:

3. Cost		
Hardware	Sensor	AR200: $1,250/unit. AR600: $2,800/unit. AR4000: $3,500/unit.
	Data acquisition system	
	Communication system	
	Data archiving system	
	Other	Acuity laser line scanner: $8,000/unit.
Software		
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	5 to 6 years (conservatively). 10 years plus life expectancy.
Power	AR200: 12 to 30V DC plus function output current. AR600: 12 to 24V DC. AR4000: 5 to 6V DC.
Environmental conditions	AR200: 0 to 60°C. AR600: 0 to 50°C. AR4000: -17 to 50°C.
Data storage/transfer/ processing	
Other:	

5. Implementation Needs	
Power source	DC.
Accessibility	Direct access needed for sensor installation.
Technical expertise	
Other:	

6. Availability
3 to 4 weeks.

7. On-Going or Completed Bridge Related Projects and References
Many applications in various industries (bridge related monitoring project not available).

8. Notes
• Laser sensors can be programmed using serial commands through a PC computer. • Optional products for AR200 laser measurement sensor include an AC/DC power supply, an alphanumeric display and a useful software library. • Options for the AR600 laser displacement sensor include a high resolution detector, an AC/DC power supply, laser power upgrades, and optical band pass filter, current loop output, a software library and an alphanumeric display. • List of recommended professional integrators of Acuity lasers into industrial applications are available on company website.

1. General Information

Description of Technology	Ultra-small MEMS sensors that can be mixed with concrete for corrosion monitoring.		
Manufacturer and Contact information	Advanced Design Consulting (ADC), Inc. PO Box 187, 126 Ridge Road, Lansing, NY 14882	www.adc9001.com Tel: (607) 533-3531 Fax: (607) 533-3618	
Features	Sensor type	Silicon-based MEMS sensors combined with radio frequency identification devices (FRIDs); tether-free, passive sensors; These detectors are a little larger than a pin-head and can be poured along with the concrete into a bridge deck or road bed.	
	Data acquisition, processing, and archiving		
	Communications	Radiation signal.	
	'Smart' attributes		
	Other	The sensors will be powered by electrical energy radiated from a hand-held monitoring device and transmit its data and identity by reradiating the signal. At other times, the sensor would remain unpowered.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☐ Timber:	☐ Plank ☐ Other:	☐ Nailed laminated	☐ Glue-laminated	☐ Prestressed laminated	☐ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☐ Steel:	☐ Grid ☐ Other:	☐ Orthotropic	☐ Buckle plate	☐ Corrugated steel flooring	
	☐ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☐ Connector and fastener: ☐ Bracing: ☐ Diaphragm ☐ Cover plate ☐ Stiffener ☐ Other:	☐ Riveted/bolted ☐ Cross	☐ Welded ☐ Lateral	☐ Pin & hanger ☐ Sway	☐ Splice	
	Bearing ☐ Fixed ☐ Expansion: ☐ Other:	☐ Sliding plate	☐ Roller	☐ Rocker	☐ Pin and link	☐ Elastomeric ☐ Pot ☐ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☒ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☐ Strand shoes 2. Movable bridge ☐ Electric brakes	☐ Main/secondary cable ☐ Cable bands ☐ Motors and power	☐ Cable anchorage ☐ Cable enclosures ☐ Operating machinery and equipment	☐ Anchor rod ☐ Other:	☐ Damping system ☐ Other:	
	Other:					

Monitoring Interest

☐ Crack/fracture	☐ Expansion/contraction	☐ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☐ Section loss	☐ Settlement	☐ Misalignment	☐ Connection failure or deficiencies
☐ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☐ Impact damage
☐ Debonding	☐ Erosion/scour	☐ Looseness and pounding	☐ Excessive joint closing/opening
☒ Corrosion	☐ Environmental	☐ Other:	

Measurement Metric

☐ Strain	☐ Deflection/displacement	☐ Acceleration/vibration	☐ Moisture/humidity level
☐ Temperature	☐ Magnetic field/flux	☒ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☒ Other: Radio frequency and Radiation signal.	

3. Cost		
Hardware	Sensor	
	Data acquisition system	
	Communication system	
	Data archiving system	
	Other	
Software		
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	Being design for an expected life of 100 years.
Power	
Environmental conditions	
Data storage/transfer/ processing	
Other:	

5. Implementation Needs	
Power source	Electrical energy radiation.
Accessibility	Can ba poured into concrete during construction.
Technical expertise	
Other:	

6. Availability

Under development.

7. On-Going or Completed Bridge Related Projects and References

Reference:

- "Making Brides Safe from Collapse: Advanced Design Consulting receives federal grant to develop MEMS sensors that can be mixed with concrete," ADC Press Release, Advanced Design Consulting, Inc.

8. Notes

- The sensor is being designed to monitor moisture, temperature, pH, and the concentration of chloride, sodium and potassium ions within the concrete.
- According to Eric Johnson, Vice President of Research at ADC, these devices are expected to provide critical data for evaluating concrete performance from its freshly mixed state to its casting, through the concrete's service life, to its period of deterioration and repair.

1. General Information

Description of Technology	Developer and supplier of high performance signal conditioning devices and sensors: analog, mixed-signal and digital signal processing (DSP) integrated circuits (ICs).	
Manufacturer and Contact information	Analog Devices Inc. (ADI) P. O. Box 9106, Norwood, MA 02062-9106	www.analog.com Tel: (800) 262-5643 or (781) 461-3333 Fax: 781-461-4482
Features	Sensor type	MEMS Accelerometers (ADXL): low-power, low-cost microcontrollers via duty cycle output, 1000g shock survival.
	Data acquisition, processing, and archiving	Various products and systems available (e.g., data converters, display electronics, integrated systems, etc). Data acquisition system is, in most cases, application specific (custom design).
	Communications	RF, Cellular handset ICs, optical networking, RS-232/422/485 transceivers, and other wireless options.
	'Smart' attributes	
	Other	Many other devices (e.g., signal processors, power supply devices, etc.) are also available.

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☐ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☒ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☒ Main/secondary cable ☒ Cable anchorage ☒ Anchor rod ☒ Damping system ☒ Strand shoes ☒ Cable bands ☒ Cable enclosures ☐ Other: 2. Movable bridge ☒ Electric brakes ☒ Motors and power ☒ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☐ Crack/fracture	☐ Expansion/contraction	☐ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☐ Section loss	☐ Settlement	☐ Misalignment	☒ Connection failure or deficiencies
☐ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☒ Impact damage
☐ Debonding	☐ Erosion/scour	☐ Looseness and pounding	☐ Excessive joint closing/opening
☐ Corrosion	☐ Environmental	☐ Other:	

Measurement Metric

☐ Strain	☐ Deflection/displacement	☒ Acceleration/vibration	☐ Moisture/humidity level
☐ Temperature	☐ Magnetic field/flux	☒ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☐ Other:	

3. Cost		
Hardware	Sensor	ADXL accelerometers: $14.44~$29.95 per unit.
	Data acquisition system	
	Communication system	
	Data archiving system	
	Other	Most products are priced based on specifications and capabilities.
Software		
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	No official life expectancy.
Power	Data acquisition and other systems can be designed to run with common power supply. ADXL accelerometer: operating voltage range of 3-5.25V.
Environmental conditions	ADXL acclerometer: -55 to 125°C operating temperature.
Data storage/transfer/ processing	
Other:	

5. Implementation Needs	
Power source	Battery, AC/DC, solar panel.
Accessibility	Direct access needed for sensor installation. Direct or remote access monitoring system (optional).
Technical expertise	Depends on product types used. Manuals for most products are available on website.
Other:	

6. Availability

1 to 4 weeks for products available in stock; longer for custom design.

7. On-Going or Completed Bridge Related Projects and References

Golden Gate Bridge, San Francisco, California.
Steel Truss Bridge at University of California, Irvine, California.
Many other bridge monitoring projects (manufacturer says the company do not keep track of all the projects).

References;

- Lynch, J.P, Partridge, A., Law, K.H., Kenny, T.W., Kiremidjian, A.S., and Carryer, E. "Design of Piezoresistive MEMS-Based Accelerometer for Integration with Wireless Sensing Unit for Structural Monitoring," Journal of Aerospace Engineering © ASCE, pp. 108-114, July 2003.
- Lynch, J., Law, K., Kiremidjian, A., Carryer, E., Kennedy, T., partridge, A., and Sundararajan, A. (2002): "Validation of a wireless modular monitoring system for structures," the SPIE 9th Annual International Symposiums on Smart Structures and Materials, San Diego, CA, March 17-21, 2002.
- Chung, H.C., Enomoto, M., Loh, K., and Shinozuka, M. "Real Time Visualization of Structural Response through Wireless Communication using MEMS Sensors," Proceedings of SPIE: Testing, Reliability, and Application of Micro- and Nano-Material Systems II, Vol. 5392, pp. 239-246, July 2004.

8. Notes

- ADI was founded in 1965, and its focus has been to solve the engineering challenges associated with signal processing in electronic equipment.
- More than 10,000 products available; ADI has served more than 60,000 customers worldwide.
- The company offers customized design; many products that can be configured or constructed for various applications are available.

1. General Information

Description of Technology	Monitoring system based on optical fiber technology.	
Manufacturer and Contact information	Advanced Optics Solutions (AOS) GmbH Ammonstrasse 35, D-01067 Dresden, Germany	www.aos-fiber.com Tel: +49 (0)351 4960 193 Fax: +49 (0)351 4960 194
Features	Sensor type	Fiber Bragg Grating temperature and strain sensors, Optical strain gauges, Displacement sensors.
	Data acquisition, processing, and archiving	Interrogators: consisting of several modules that can easily be combined with each other; can be used for the long-term strain or temperature monitoring of structures and for the measuring of vibrations. Fully developed software is capable of displaying strain/temperature, storing data, and supporting time shift and/or trigger mode.
	Communications	Direct wire connection, Ethernet, Internet.
	'Smart' attributes	Automatic calibration, optical connector test and time-control.
	Other	Optical channel can be expended to 2, 4, 8, 16 input channels for all units. For a multi-channel unit, the software provides a capability of on-line monitoring and saving data for all channels simultaneously.

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☒ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☐ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☒ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☒ Main/secondary cable ☒ Cable anchorage ☒ Anchor rod ☒ Damping system ☒ Strand shoes ☒ Cable bands ☒ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☒ Crack/fracture	☒ Expansion/contraction	☒ Rotation/torsion	☒ Wear/spalling/scaling/delamination
☒ Section loss	☒ Settlement	☒ Misalignment	☒ Connection failure or deficiencies
☒ Deformation	☒ Wire breakage	☒ Mechanical/electrical malfunction	☒ Impact damage
☒ Debonding	☒ Erosion/scour	☒ Looseness and pounding	☒ Excessive joint closing/opening
☐ Corrosion	☒ Environmental	☒ Other: Seismic activity.	

Measurement Metric

☒ Strain	☒ Deflection/displacement	☐ Acceleration/vibration	☐ Moisture/humidity level
☒ Temperature	☐ Magnetic field/flux	☐ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☐ Other:	

3. Cost		
Hardware	Sensor	FBG temperature and strain sensors: ~$550 (temperature probe), $800 (embeddable strain sensor) per unit. Optical strain gauge (prelaminated): ~$350 per unit.
	Data acquisition system	Interrogators: $6,000~$15,000 (single channel), $13,000~$25,000 (multiple channel).
	Communication system	
	Data archiving system	
	Other	
Software		
Labor	Installation	
	Use	Free of maintenance once installed. However, AOS recommends a two-year maintenance interval to ensure highet accuracy and reliability.
Other:		

4. Limitations	
Life expectancy	No official life expectancy.
Power	12V DC. 110/230V AC.
Environmental conditions	Interrogator: 5 to 50°C without air-conditioning. FBG sensors: -60 to 120°C.
Data storage/transfer/ processing	Disc space of Internal PC: 20GB (hard disc). Interrogator sample rate: 30 samples/sec (2 channel module), 500 samples/sec (1 channel module).
Other: Wavelength range: 1540-1560 nm (other wavelengths on request). FBG sensor parameters: >90% reflection, >200pm bandwidth (FWHM).	

5. Implementation Needs	
Power source	AC/DC.
Accessibility	Direct access needed for sensor installation and data acquisition. Remote data acquisition and control optional.
Technical expertise	Knowledge of FBG required. AOS offers their support throughout project.
Other: System running on Windows 95/98 or greater. File format:ASCII.	

6. Availability

2 to 7 weeks.

7. On-Going or Completed Bridge Related Projects and References

Project information not available.

Reference:

• Meissener, J., and Baumann, I. (2000) "Blast Vibration and Strain Monitoring by Fiber Bragg Grating Sensors," submitted to OFS2000 in Venice.

8. Notes

- AOS has been designing and producing various Fiber Bragg Gratings products and related components over 12 years; US distributer of AOS GmbH is Advanced Photonics International, Inc. (Tel: 914-347-7732 , www.advancedphotonicsintl.com).
- AOS's sensors can be integrated directly into structures; once implemented, there is no need for calibrtion or maintenance during its lifetime. Sensors also can be fixed to existing structures.
- Each standard unit consisting of 4 channels can measure 4 optical FBG sensors simultaneously with a speed of up to 30 samples per second.
- If more channels, or measuring of an array of FBG sensors, are required, the number of modules can be increased easily. The sample rate can also be increased up to 500 Hz by special design of the module.
- For long-term monitoring, the unit is combind with an internal PC as a stand alone device which stores and displays the data internally.
- Two types of the interrogation units can be equipped with analog outputs or digital RS232 interface for an external PC or laptop.

1. General Information

Description of Technology	Various sensors and instrumentations: specialty in trancducers.		
Manufacturer and Contact information	Applied Measurements, Ltd. 3 Mercury, Calleva Park, Aldermaston, Berkshire RG7 8PN. UK.	www.appmeas.co.uk Tel: +44 (0) 118 981 7339 Fax: +44 (0) 118 981 9121	
Features	Sensor type	Strain gauges, load cells, pressure sensors, torque transducers, and displacement transducers (AML/IE/M/E series).	
	Data acquisition, processing, and archiving	Applied Measurements are an approved distibutor for analog and digital instumentation, and data acquisition system, manufactured by Mantracourt Electronics Ltd. (http://www.mantracourt.co.uk).	
	Communications		
	'Smart' attributes		
	Other	AML/IE displacement transducers: ±0.5mm to ±550mm range; manufactured from stainless steel, sealed to IP65 (IP68) optional with armoured cable.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☒ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☒ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☒ Main/secondary cable ☒ Cable anchorage ☒ Anchor rod ☒ Damping system ☒ Strand shoes ☒ Cable bands ☒ Cable enclosures ☐ Other: 2. Movable bridge ☒ Electric brakes ☒ Motors and power ☒ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☒ Crack/fracture ☒ Expansion/contraction ☒ Rotation/torsion ☒ Wear/spalling/scaling/delamination
☐ Section loss ☒ Settlement ☒ Misalignment ☒ Connection failure or deficiencies
☒ Deformation ☐ Wire breakage ☒ Mechanical/electrical malfunction ☒ Impact damage
☒ Debonding ☐ Erosion/scour ☒ Looseness and pounding ☒ Excessive joint closing/opening
☐ Corrosion ☒ Environmental ☐ Other:

Measurement Metric

☒ Strain ☒ Deflection/displacement ☐ Acceleration/vibration ☐ Moisture/humidity level
☐ Temperature ☐ Magnetic field/flux ☐ Electrical voltage/current ☐ Chemical composition
☐ Radar waves ☐ Acoustic waves ☐ Magnetic waves ☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☐ Wind speed/direction ☐ Other:

3. Cost		
Hardware	Sensor	Displacement transcuders (LVDTs), AML/IE Series: $455-546 per unit (£1.00 = $1.82).
	Data acquisition system	
	Communication system	
	Data archiving system	
	Other	
Software		
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	No official life expectancy.
Power	AML/IE Series: supply voltage of 10 to 30V DC, and supply current of 35mA at 15V or 12V.
Environmental conditions	-30 to 85°C (-30 to 150°C optional upon request).
Data storage/transfer/ processing	
Other: Output band width: 180 to 300 Hz. Stroke measurement range: ±0.5 to ±550mm. Maximum loop resistance: 300 ohms@30V.	

5. Implementation Needs	
Power source	AC/DC.
Accessibility	Direct access needed for sensor installation.
Technical expertise	Basic instrumentation skills.
Other:	

6. Availability

Upon agreement.
All products supplied and manufactured by Applied Measurements are supported with a 3-Year Warranty.

7. On-Going or Completed Bridge Related Projects and References

Information not available.

8. Notes

• Applied Measurements Limited was founded in 1991.
• They offer customized design and manufacturing service for specific requirements or applications.

1. General Information

Description of Technology	Diagonostic Network Patch (DNP) System for real-time monitoring and forecasting structural condition.		
Manufacturer and Contact information	Advanced Structure Monitoring (ASM), Inc. 21070 Homestead #200, Cupertino, CA 95014	www.asmonitoring.com Tel: (408)-481-9030 Fax: (408)-481-9031	
Features	Sensor type	DNP sensors: a coin-sized, thin multilayered disk containing a piezoelectric device for actuator, sensor and a coated circular plate of optical fiber loops for twofold sensor; either bonded onto or inserted into the structure.	
	Data acquisition, processing, and archiving	DNP Datalogger: a portable instrument (notebook computer) designed to interface with the DNP sensors and actuators; diagnostic software provides an integrated robust system for structural health monitoring; interface channels of up to 30 actuators and sensors; diagnostic software to provide an integrated robust system. DNP Server: dedicated web-based database server with scanned-tomography imaging system.	
	Communications	The system is LAN-based.	
	'Smart' attributes	Self-sensing nervous system for damage identification, classification and prognosis.	
	Other	DNP can integrate other types of sensors (i.e., strain gage, pressure, temperature, moisture, etc.) to examine physical properties of a structure.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☒ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☐ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☐ Main/secondary cable ☒ Cable anchorage ☒ Anchor rod ☒ Damping system ☒ Strand shoes ☒ Cable bands ☒ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☒ Crack/fracture ☒ Expansion/contraction ☐ Rotation/torsion ☐ Wear/spalling/scaling/delamination
☒ Section loss ☒ Settlement ☐ Misalignment ☒ Connection failure or deficiencies
☐ Deformation ☐ Wire breakage ☐ Mechanical/electrical malfunction ☒ Impact damage
☐ Debonding ☐ Erosion/scour ☐ Looseness and pounding ☐ Excessive joint closing/opening
☐ Corrosion ☒ Environmental ☐ Other:

Measurement Metric

☐ Strain ☐ Deflection/displacement ☐ Acceleration/vibration ☐ Moisture/humidity level
☐ Temperature ☐ Magnetic field/flux ☐ Electrical voltage/current ☐ Chemical composition
☐ Radar waves ☐ Acoustic waves ☐ Magnetic waves ☒ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☐ Wind speed/direction ☒ Other: the system generates tomography images.

3. Cost		
Hardware	Sensor	Piezo: $6,000 per unit. Optic: $24,000 per unit.
	Data acquisition system	$17,000~$32,000 (one unit covering 30 sensors/actuators).
	Communication system	
	Data archiving system	
	Other	
Software	1. $50,000 (web-based database system without SHM modules); 2. $120,000 (1 plus basic interrogation modules); 3. $180,000 (2 plus processing modules for tomographies); 4. $240,000 (3 plus damage classification modules); $320,000 (4 plus forecasting/state awareness modules).	
Labor	Installation	$50/hour/man
	Use	
Other:		

4. Limitations	
Life expectancy	No official life expectancy.
Power	110/230V AC.
Environmental conditions	
Data storage/transfer/ processing	
Other:	

5. Implementation Needs	
Power source	Battery, AC/DC.
Accessibility	Direct access needed for sensor installation and data acquisition.
Technical expertise	Engineering background. Moderate training on how to use the system.
Other:	

6. Availability

Upon agreement (depending on complexity of the system).

7. On-Going or Completed Bridge Related Projects and References

Has not been used on bridge structures yet.

8. Notes

- ASM was founded in 2003 and is primarily engaged in the development and commercialization of the DNP System.
- According to the manufacturer, DNP is the first scanned-image-based SHM system for damage identification.
- The thin multilayered disk is used as an extra film patch that is either bonded onto or inserted into the structure to have it admit diagnostic signals. The network of built-in sensors/actuators is employed to monitor the structural condition of the host structure by interrogating the wave signals of the structure through its service life.
- The DNP Datalogger has the built-in capability to energize the piezoelectric devices embedded in the DNP patches and record the measurement signals of neighboring piezoelectric sensors and fiber-optic loop sensors.
- DNP system can be custom designed to meet specific applications.
- According to the manufacture, the DNP can be used on any materials (e.g., concrete, steel, timber, etc), but it apprears most suitable for composite and metal structures.

1. General Information

Description of Technology	Digital wireless telemetry technology for remote monitoring system.	
Manufacturer and Contact information	Advanced Telemetrics International (ATI) 2361 Darnell Drive, Spring Valley, OH 45370	www.atitelemetry.com Tel: (937) 862-6948 Fax: (937) 862-7193
Features	Sensor type	
	Data acquisition, processing, and archiving	ATI 2000 series: Model 3024 Mainframe, with up to four 3022D-M4 receiver modules, can monitor up to 16 channels; Model 3025, with up to eight 3022D-M4 receiver modules can monitor up to 32 channels; The 3025 mainframe can interface with up to 16 transmitters, and two of these systems could be used on the same bridge, for a total of 32 channels; Continuous analog outputs per channel are provided.
	Communications	Radio frequency (RF) telemetry: Model 2060B series transmitters, housed in a weatherproof NEMA 4x enclosure, supply excitation to sensors and can transmit up to 4 miles (line of sight).
	'Smart' attributes	Remote transmitters connect directly to strain or displacement sensors and transmit signals to a conveniently located stationary receiver.
	Other	System bridges the gap between bridge mounted sensors and data recording equipment; eliminating cabling/wiring efforts.

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☒ Nailed laminated ☒ Glue-laminated ☒ Prestressed laminated ☒ Stressed timber ☐ Other:
	☒ Concrete:	☒ Reinforced ☒ Prestressed/post-tensioned ☐ Other:
	☒ Steel:	☒ Grid ☒ Orthotropic ☒ Buckle plate ☒ Corrugated steel flooring ☐ Other:
	☒ FRP:	
Superstructure	*Primary Element*	☒ Multi-beam/girder system: ☒ Girder floor beam/diaphragm system ☒ Tee beam ☒ Box girder ☒ Channel beam ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:
	Secondary Element	☒ Connector and fastener: ☒ Riveted/bolted ☒ Welded ☒ Pin & hanger ☒ Splice ☒ Bracing: ☒ Cross ☒ Lateral ☒ Sway ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:
	Bearing	☒ Fixed ☒ Expansion: ☒ Sliding plate ☒ Roller ☒ Rocker ☒ Pin and link ☒ Elastomeric ☒ Pot ☒ Restraining ☐ Other:
	Other:	
Substructure	☒ Abutment:	☒ Footing ☒ Bridge seat ☒ Piles ☒ Wall (stem/back/wing) ☐ Other:
	☒ Pier/bent/extended pile:	☒ Pier cap ☒ Shaft ☒ Column/stem ☒ Submerged pile/pile cap/footing ☐ Other:
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)*	1. Cable-supported bridge ☒ Tower ☒ Main/secondary cable ☒ Cable anchorage ☒ Anchor rod ☒ Damping system ☒ Strand shoes ☒ Cable bands ☒ Cable enclosures ☐ Other: 2. Movable bridge ☒ Electric brakes ☒ Motors and power ☒ Operating machinery and equipment ☐ Other:
	Other:	

Monitoring Interest

☐ Crack/fracture ☐ Expansion/contraction ☐ Rotation/torsion ☐ Wear/spalling/scaling/delamination
☐ Section loss ☐ Settlement ☐ Misalignment ☐ Connection failure or deficiencies
☐ Deformation ☐ Wire breakage ☐ Mechanical/electrical malfunction ☐ Impact damage
☐ Debonding ☐ Erosion/scour ☐ Looseness and pounding ☐ Excessive joint closing/opening
☐ Corrosion ☐ Environmental ☐ Other:

Measurement Metric

☐ Strain ☐ Deflection/displacement ☐ Acceleration/vibration ☐ Moisture/humidity level
☐ Temperature ☐ Magnetic field/flux ☐ Electrical voltage/current ☐ Chemical composition
☐ Radar waves ☐ Acoustic waves ☐ Magnetic waves ☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☐ Wind speed/direction ☐ Other:

3. Cost		
Hardware	Sensor	
	Data acquisition system	Model 3024 Mainframe: $2,450 per unit. Model 3023-M4 Receiver module: $1,850 per unit.
	Communication system	Model 2060D Transmitter: $3,480 per unit.
	Data archiving system	
	Other	
Software		
Labor	Installation	
	Use	
Other: The total price for an eight-channel system: $35,750.		

4. Limitations	
Life expectancy	20 years.
Power	Transmitter: internal rechargable battries or external 9V DC supply. Receivers: 12V DC or 115/230V AC. Mainframe: 12V DC or 120V AC.
Environmental conditions	-40°C to 85°C.
Data storage/transfer/ processing	Data sampling: 300 samples/second/channel. RF range: up to 10 km. RF output: 10,000 µV/M@3M
Other:	

5. Implementation Needs	
Power source	Two internal batteries or rechargeable batteries for transmitters. AC/DC for receivers.
Accessibility	Remote data acquisition and control.
Technical expertise	Basic electronics handling skills.
Other:	

6. Availability
Upon agreement.

7. On-Going or Completed Bridge Related Projects and References
Bridge monitoring and testing projects at University of Michigan.

8. Notes
• ATI, founded in 1987, offers a variety of strain gage based transducers, but can also supply a complete system including third party sensors and a notebook PC-based data acquisition system (they could configure the transmitters to connect directly with most any type of commercially available transducers). • Additional features of ATI 2000 series include: immune to electromagnetic interference, dust, oil, moisture, etc.; remote trun-on/off of the transmitters from the receiver; transmitter auto turn off when battery too low (prevents damage to the battery); autozero for eah channel at receiver; transmitter battery-low and data transmission status indicatiors at receiver; initial offset indicators at transmitter (indicates if exessive offset present).

1. General Information

Description of Technology	Load rating and structural testing and (short- and long-term) monitoring technologies for small to medium span bridges.		
Manufacturer and Contact information	Bridge Diagnostics, Inc. (BDI) 5398 Manhattan Circle, Suite 100, Boulder, CO 80303-4239	www.bridgetest.com Tel: (303) 494-3230 Fax: (303) 494-5027	
Features	Sensor type	Strain transducers (Intelliducers): wheatstone bridge strain transducers can be integrated with most standard data acquisition systems.	
	Data acquisition, processing, and archiving	BDI Structural Monitoring System (STS): portable, lightweight equipments designed for performing live-load testing and rating on bridge structure; units are connected in series and mounted on the structure; only one cable runs from the PC/Power Supply to the bridge. BDI AutoClicker was developed for monitoring the position of testing vehicle as it crosses the structure at crawl speed; interfaces with many types of data acquisition systems.	
	Communications	Direct wire connection. Wireless communication optional.	
	'Smart' attributes	Easy-to-use BDI WinSTS control software allows control over sampling rates, test durations, and the automatic transducer circuit balancing.	
	Other	The collected data can be displayed during the test and then shown as a function of load position when the test is completed. BDI-STSII can accommodate LVDT's, accelerometers, and other full-bridge type sensors.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☐ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☐ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☐ Cover plate ☒ Stiffener ☐ Other:	☐ Riveted/bolted ☒ Cross	☐ Welded ☒ Lateral	☐ Pin & hanger ☒ Sway	☐ Splice	
	Bearing ☐ Fixed ☐ Expansion: ☐ Other:	☐ Sliding plate	☐ Roller	☐ Rocker	☐ Pin and link	☐ Elastomeric ☐ Pot ☐ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☐ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☐ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☐ Strand shoes 2. Movable bridge ☐ Electric brakes	☐ Main/secondary cable ☐ Cable bands ☐ Motors and power	☐ Cable anchorage ☐ Cable enclosures ☐ Operating machinery and equipment	☐ Anchor rod ☐ Other:	☐ Damping system ☐ Other:	
	Other:					

Monitoring Interest

☐ Crack/fracture	☐ Expansion/contraction	☐ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☐ Section loss	☐ Settlement	☐ Misalignment	☐ Connection failure or deficiencies
☐ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☐ Impact damage
☐ Debonding	☐ Erosion/scour	☐ Looseness and pounding	☐ Excessive joint closing/opening
☐ Corrosion	☐ Environmental	☒ Other: Load testing and rating.	

Measurement Metric

☒ Strain	☒ Deflection/displacement	☐ Acceleration/vibration	☐ Moisture/humidity level
☐ Temperature	☐ Magnetic field/flux	☐ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☐ Other:	

3. Cost		
Hardware	Sensor	Standard BDI strain transducer: $495 (aluminum), $535 (steel), $1,260 (waterproofed) per unit.
	Data acquisition system	Complete BDI STS (including all electrical components, test software, auto clicker, cables and sensor installation tools: $24,560 (4 channels); $48,440 (16 channels); $80,280 (32 channels); $96,200 (40 channels); $112,120 (48 channels); $143,960 (64 channels).
	Communication system	
	Data archiving system	
	Other	Individual components: 4-channel STS unit ($3,995); Power supply ($6,950); Automatic load position indicator/AutoClicker ($5,950); manual remote load position indicator ($3,880); Spare intelliducer with connector ($890 each); Cable splitter ($620); Transit case ($560).
Software	BDI WinGen Anslysis software for Windows: $4,500.	
Labor	Installation	
	Use	
Other: Sensor installation tools: Transducer Tabs ($4.55 each); Jig ($88 each); Extension ($85 each); Adhesive ($19.50 per 20 gram bottle); Accelerator ($18.20 per spary bottle).		

4. Limitations	
Life expectancy	No official life expectancy.
Power	110/220V AC generator or a 12VDC battery.
Environmental conditions	-25 to 55°C.
Data storage/transfer/ processing	Sample Rates: 0.01 to 1,000 Hz, Internal over-sampling rate is 15 KHz. Max. Test Lengths: 20 minutes at 100Hz; 128K samples per channel maximum test length. Data is stored in ASCII file format.
Other: Accuracy: ± 0.2% (2% for Strain Transducers). Max. Test Lengths: 20 minutes at 100Hz; 128K samples per channel maximum test length.	

5. Implementation Needs	
Power source	Battery, AC/DC.
Accessibility	Direct access needed for sensor installation and data acquisition (remote data acquisition optional).
Technical expertise	Moderate training on how to use the system and software.
Other: PC Requirements: Windows 2000, XP.	

6. Availability

2 to 5 weeks.

7. On-Going or Completed Bridge Related Projects and References

Steel Pony Truss Bridge, Butler County, Ohio.
Fairground Road Bridge, Green County, Ohio.

References:

- Phares, B.M, Wipf, T.J., and Abu-Hawash, A. "Bridge Load Rating Using Physical Testing," Proceedings of Mid-Continent Transportation Research Symposium, Iowa State University, Ames, Iowa, August 2003.
- BDI STS has been used over 200 structures. Many other projects and references are available on company website.

8. Notes

- BDI has been manufacturing and providing bridge testing and monitoring equipments and services since 1989; BDI uses a well-established set of procedures for both the field tests and analytical work.
- The basic approach of BDI testing and analysis is very similar to that used in both standard highway and railroad bridge design codes, with only exception being that instead of relying on estimated distribution factors and assumed member behaviors, actual field data is used to develop an accurate analytical model of the structure for developing the rating factors. Since the model has been actively "calibrated" with field data, it represents the live load distribution behavior such as end-restraints that simply cannot be accurately assumed. This approach is suitable for structures that have a low load rating based on the standard methods and on structures that appear damaged.
- BDI also offers equipments and services for long-term monitoring systems for tracking bridge behavior over time. Most of these systems use sensors that are based on Vibrating Wire (VW) technology and track parameters such as crack growth, strains, and rotations. These systems can be fielded for years at a time and can be accessed remotely via cellular or land telephone lines. They can also be configured with an Alarm Mode which will automatically contact a PC or pager if something detrimental is detected by the system.

1. General Information

Description of Technology	Short- and long-term monitoring system; BDI Structural Monitoring System (BDI-SMS) is designed for tracking structural movement or degradation over long periods of time.		
Manufacturer and Contact information	Bridge Diagnostics, Inc. (BDI) 5398 Manhattan Circle, Suite 100, Boulder, CO 80303-4239	www.bridgetest.com Tel: (303) 494-3230 Fax: (303) 494-5027	
Features	Sensor type	Strain transducers, vibrating wire (VW) sensors, crack and tiltmeters, temperature sensors. Sensors can be attached with adhesive for short-term or permanently mounted with anchor bolts or welding for long-term monitoring.	
	Data acquisition, processing, and archiving	Basic 16-channel system: including datalogger, customized software, baterry-backed power supply, multiplexer, signal conditioning, PC communication interface; wired in 16"x18" fiberglass housing. The BDI-SMS can be configured by the user to record data for a few days, weeks, months, or years. Maximum number of channels: 96 VW sensors, each with internal thermistor.	
	Communications	Data can be downloaded via telephone modem and be remotely viewed in real time or automatically stored on a periodic basis.	
	'Smart' attributes	BDI-SMS can be set to trigger an alarm in case the designated threshold level on one or more of the sensors is exceeded.	
	Other	Data can be recorded manually or automatically. For locations without power or phone lines available, the BDI-SMS can use its own cellular phone for communications and solar panels for power.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☒ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☐ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☐ Main/secondary cable ☐ Cable anchorage ☐ Anchor rod ☐ Damping system ☐ Strand shoes ☐ Cable bands ☐ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☒ Crack/fracture ☐ Expansion/contraction ☒ Rotation/torsion ☐ Wear/spalling/scaling/delamination
☐ Section loss ☒ Settlement ☒ Misalignment ☐ Connection failure or deficiencies
☒ Deformation ☐ Wire breakage ☐ Mechanical/electrical malfunction ☒ Impact damage
☐ Debonding ☐ Erosion/scour ☐ Looseness and pounding ☐ Excessive joint closing/opening
☐ Corrosion ☒ Environmental ☒ Other: Creep, rotation or tilt of piers, etc.

Measurement Metric

☒ Strain ☒ Deflection/displacement ☒ Acceleration/vibration ☒ Moisture/humidity level
☒ Temperature ☐ Magnetic field/flux ☐ Electrical voltage/current ☐ Chemical composition
☐ Radar waves ☐ Acoustic waves ☐ Magnetic waves ☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☒ Wind speed/direction ☐ Other:

3. Cost		
Hardware	Sensor	Crackmeters (including 10 ft BDI BC-250 cable, mounts, aluminum cover): $475 per unit. Strain gages (including 10 ft BDI RC-125 cable, mount, aluminum cover): $275 per unit. Tiltmeter (including 10 ft BDI BC-250 cable, mount, aluminum cover): $925 per unit. Thermistor (PVC temperature sensor, embeddable): $85 per unit. Temperature/humidity probe (including 10 ft cable and radiation shield): $725 per unit.
	Data acquisition system	Basic 16-channel SMS ($10,500); Additional 16-channel multiplexer/MUX ($950); Handheld VW readout system with flying leads ($1,650).
	Communication system	Standard communication modem for use with land-line phone connection ($450); Digital cellular phone modem with mounting kit ($750); Antenna for use with cellular modom with 10 ft cable ($225).
	Data archiving system	
	Other	20-Watt solar panel with internal regulator ($610); PVC housing for remote MUX ($125); 20-Watt solar panel with internal regulator; ($610).
Software		
Labor	Installation	
	Use	
Other: Interconnet cable for remote MUX ($1.10/ft); Standard Red VW sensor-to-MUX and thermistor interconnect extensoion cable ($0.55/ft). Rental of BDI long-term monitoring equipments are also available: $8~$15/week, $32~$60/month for sensor; $75~$200/week, $300~$800/month for data logger; $500 for one time use of data logger; plus additional rental cost for accessories.		

4. Limitations	
Life expectancy	No official life expectancy.
Power	12VDC, use AC adapter, 12V marine battery, or solar panel.
Environmental conditions	-35°C to 50°C.
Data storage/transfer/ processing	Maximum scan rate: Approximately 1 sample/sec. per sensor (sequential sampling).
Other: Lead wire length per sensor: up to 6,000 ft (1,800 m). Wind speed & direction sensor: 0 to 130 mph (60m/sec), 360°, mounts to 1" pipe.	

5. Implementation Needs	
Power source	Battery, AC/DC, solar panel.
Accessibility	Direct access needed for sensor installation. Data can be collected at remote site.
Technical expertise	Moderate training on how to use the system.
Other:	

6. Availability

Upon agreement (depending on complexity of the system).

7. On-Going or Completed Bridge Related Projects and References

Some literatures and references are available on company website.

8. Notes

- BDI has been manufacturing and providing bridge testing and monitoring equipments and services since 1989.
- All hardware are rugged and has been field-proven to be reliable, even in harsh conditions.
- VW sensors are manufactured by Geokon, Inc. (www.geokon.com; 603-448-1562), and data logging hardware components are manufactured by Campbell Scientific, Inc. (www.campbellsci.com; 435-750-9558).
- BDI also offers Structural Monitoring System (BDI-STS II): portable, lightweight equipments designed for performing live-load testing and rating on small to medium span bridge structures.

1. General Information

Description of Technology	Fiber optic sensor technology for static and dynamic measurements.		
Manufacturer and Contact information	Blue Road Research 376 NE 219th Ave., Gresham, OR 97030	www.bluerr.com Tel: (503) 667-7772 Fax: (503) 667-7880	
Features	Sensor type	Multi-axis Fiber grating sensors: the long gage sensor avoids problems arising from local stress concentrations while maintaining durability and resistance to electromagnetic interference. These sensors can be used alone or combined with temperature, humidity, or corrosion sensors to monitor structural health.	
	Data acquisition, processing, and archiving	Readout systems (including light sources, filters, and detectors in integrated or modular configurations): spliced in a single enclosure or modular, using FC/APC optical connections and patch cables. DAQ software: user friendly graphical interfaces to perform data logging and first order processing of data.	
	Communications	Direct wire connection. Ethernet/Internet. Other communication available upon request.	
	'Smart' attributes	Real-time monitoring of structural dynamic and quantified loading data for use in performance analyses.	
	Other	The systems may be permanently installed or removable, and continuously or periodically monitored.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☒ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☐ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☒ Main/secondary cable ☒ Cable anchorage ☒ Anchor rod ☒ Damping system ☒ Strand shoes ☒ Cable bands ☒ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☒ Crack/fracture ☐ Expansion/contraction ☐ Rotation/torsion ☐ Wear/spalling/scaling/delamination
☐ Section loss ☒ Settlement ☐ Misalignment ☒ Connection failure or deficiencies
☒ Deformation ☐ Wire breakage ☐ Mechanical/electrical malfunction ☒ Impact damage
☒ Debonding ☐ Erosion/scour ☐ Looseness and pounding ☐ Excessive joint closing/opening
☐ Corrosion ☒ Environmental ☒ Other: Static and dynamic measurements for performance analyses.

Measurement Metric

☒ Strain ☐ Deflection/displacement ☒ Acceleration/vibration ☐ Moisture/humidity level
☒ Temperature ☐ Magnetic field/flux ☐ Electrical voltage/current ☐ Chemical composition
☐ Radar waves ☐ Acoustic waves ☐ Magnetic waves ☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☐ Wind speed/direction ☐ Other:

3. Cost		
Hardware	Sensor	$900 per unit.
	Data acquisition system	Readout system: $15,000~$25,000 depending on specification.
	Communication system	
	Data archiving system	
	Other	
Software	Included.	
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	No official life expectancy. One of their systems has been used since 1998-present (2004).
Power	Two 9V batteries (High-speed detector, general purpose receiver). 110/220V AC.
Environmental conditions	Grating Filter: 0 to 50°C. Spliter and multiplexer: -40°C to 85°C
Data storage/transfer/ processing	Optical interface: FC/APC. I/O interface: RS232.
Other:	

5. Implementation Needs	
Power source	Battery, AC/DC.
Accessibility	Direct access needed for sensor installation and data acquisition.
Technical expertise	Basic electronics skills. Knowledge of dynamics. Moderate training on how to use the system.
Other:	

6. Availability

Upon agreement.

7. On-Going or Completed Bridge Related Projects and References

Horsetail Falls Bridge, Oregon.
Broadway Bridge, Oregon.

References:

- Udd, E., Kreger, S., Calvert, S., Kunzler, M., and Davol, K. "Usage of Multi-Axis Fiber Grating Strain Sensors to Support Nondestructive Evaluation of Composite Parts and Adhesive Bond Lines," Structural Health Monitoring Workshop, Stanford University, California, 2003.
- Kreger, S., Calvert, S., and Udd, E. "Optical Frequency Domain Reflectometry for High Density Multiplexing of Multi-Axis Fiber Bragg Gratings," Proceedings of OFS-16, Nara, Japan, 2003.
- Udd, E., Calvert, S., and Kunzler, M. "Usage of Fiber Grating Sensors to Perform Critical Measurements of Civil Infrastructure," Proceedings of OFS-16, Nara, Japan, 2003.
- Seim, J., Udd, E., Schulz, W.L, Morrell, M., Laylor, H.M. "Health Monitoring of an Oregon Historical Bridge with Fiber Grating Strain Sensors," SPIE Proceedings, Vol. 3671, p. 128, 1999.
- Many other references available on the company website.

8. Notes

- Blue Road Research was founded in 1993 and has provided products and applied R&D for various sensing and measurement applications.
- The company offers technology development, on-site customer support, continuous research and development, and educational services.
- Additional features of fiber optic sensor system include: High-speed readout techniques; High resistance to EMI and corrosion; Customizable range and sensitivity to meet various sensing demands; Multiplexing capabilities allowing mutiple sensors to be monitored on a single fiber.

1. General Information

Description of Technology	Fiber optic sensor technology.	
Manufacturer and Contact information	Bragg Photonics, Inc./Avensys, Inc. 880 Selkirk, Pointe-Claire, Montreal (Quebec) Canada.	www.braggphotonics.com www.avensys.ca Tel: (514) 428-6766 Fax: (514) 428-8999
Features – Sensor type	Fiber Bragg Grating (FBG) sensors: immunte to EMI/RFI; self calibrating; no need for reference sensor; low insertion loss (Bandwidth @-3 dB: 0.3 nm. Minimum reflectivity: 90%).	
Features – Data acquisition, processing, and archiving	Interrogator is under development.	
Features – Communications		
Features – 'Smart' attributes		
Features – Other	Fiber type: SMF28 SM fiber/Polymide SM fiber. Recoating: acrylate/plyimide. FBG sensors are either embeddable or surface mountable.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☒ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☒ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☒ Main/secondary cable ☒ Cable anchorage ☒ Anchor rod ☒ Damping system ☒ Strand shoes ☒ Cable bands ☒ Cable enclosures ☐ Other: 2. Movable bridge ☒ Electric brakes ☒ Motors and power ☒ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☐ Crack/fracture ☐ Expansion/contraction ☐ Rotation/torsion ☐ Wear/spalling/scaling/delamination
☐ Section loss ☐ Settlement ☐ Misalignment ☐ Connection failure or deficiencies
☐ Deformation ☐ Wire breakage ☐ Mechanical/electrical malfunction ☐ Impact damage
☐ Debonding ☐ Erosion/scour ☐ Looseness and pounding ☐ Excessive joint closing/opening
☐ Corrosion ☐ Environmental ☐ Other:

Measurement Metric

☒ Strain ☐ Deflection/displacement ☐ Acceleration/vibration ☐ Moisture/humidity level
☒ Temperature ☐ Magnetic field/flux ☐ Electrical voltage/current ☐ Chemical composition
☐ Radar waves ☐ Acoustic waves ☐ Magnetic waves ☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☐ Wind speed/direction ☐ Other:

3. Cost		
Hardware	Sensor	FBG sensor Grating on SM fiber: $90~$100 per unit. FBG sensors (ready to use): typically around $150 per unit.
	Data acquisition system	Interrogator: $13,000 (expected price).
	Communication system	
	Data archiving system	
	Other	Sensors are priced based on capabilities and specifications.
Software		
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	No official life expectancy.
Power	
Environmental conditions	
Data storage/transfer/ processing	
Other: Center wavelength tolerance: ±0.5 nm Maximum grating length: 10 nm. Proof test: >100 kpsi.	

5. Implementation Needs	
Power source	
Accessibility	
Technical expertise	
Other:	

6. Availability

Upon agreement; approximately 3 to 6 weeks (based on sensor specification and added packaging).
Interrogator will be available soon (the development is almost completed).

7. On-Going or Completed Bridge Related Projects and References

East 12th Street Bridge over I-235, Des Moines, Iowa - Iowa State University.
Several technical reports and references are available on company website.

8. Notes

- Bragg Photonics, Inc. was formed in 1995 to design, manufacture and market phase masks and fiber grating based solutions.
- The company offers custom designed products (fully customizable attenuation bandwidth).

1. General Information

Description of Technology	Customized structural health monitoring system; from basic system with a few channels to expandable systems that measures hundreds of channels.		
Manufacturer and Contact information	Campbell Scientific, Inc. (CSI) 815 West 1800 North, Logan, UT 84321	www.campbellsci.com Tel: (435) 750-9558 Fax: (435) 750-9540	
Features	Sensor type	Vibrating wire sensor, SDI-12, thermocouple, strain gage, accelerometer, load cell, LVDT, PRT, tiltmeter, GPS, infrared, non-contact laser (compatible with most commercially available sensors).	
	Data acquisition, processing, and archiving	CR9000, CR9000C, CR5000, CR10X and many others; all data acquisition systems are based on the same measurement concepts; on-board real-time clocks data acquisition systems (accurate to 30 seconds per month); scan rates can be programmed from a few hours to 100,000 times per second; up to large 100+ channels systems; on-board processing system (no post processing required); server-based archiving system.	
	Communications	Direct connections, radio links, techphone links, cellular phone, short haul modem, ethernet, spread spectrum radio, MD9 network, internet, and combination. Data retrieval via satellite for very remote applications possible.	
	'Smart' attributes	Automatic sound alarms and actuation of electrical devices based on time or measured conditions; the system can be programmed to automatically alert engineers via mobile phones, pagers, radios, etc. in alarming situation.	
	Other	Measurement types, recording intervals, and processing algorithms are also programmable. Data loggers are capable of measurements, as well as controling external devices.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☒ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☒ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☒ Main/secondary cable ☒ Cable anchorage ☒ Anchor rod ☒ Damping system ☒ Strand shoes ☒ Cable bands ☒ Cable enclosures ☐ Other: 2. Movable bridge ☒ Electric brakes ☒ Motors and power ☒ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☒ Crack/fracture ☒ Expansion/contraction ☒ Rotation/torsion ☒ Wear/spalling/scaling/delamination
☒ Section loss ☒ Settlement ☒ Misalignment ☒ Connection failure or deficiencies
☒ Deformation ☒ Wire breakage ☒ Mechanical/electrical malfunction ☒ Impact damage
☒ Debonding ☒ Erosion/scour ☒ Looseness and pounding ☒ Excessive joint closing/opening
☒ Corrosion ☒ Environmental ☐ Other:

Measurement Metric

☒ Strain ☒ Deflection/displacement ☒ Acceleration/vibration ☒ Moisture/humidity level
☒ Temperature ☐ Magnetic field/flux ☒ Electrical voltage/current ☐ Chemical composition
☒ Radar waves ☐ Acoustic waves ☐ Magnetic waves ☒ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☒ Wind speed/direction ☐ Other:

3. Cost		
Hardware	Sensor	$120~ (depending on types of sensors).
	Data acquisition system	$2000~$30,000 depending on technology, measurement speed, and number of measurements needed.
	Communication system	Direct connect is built in. Modem, cell phone, RF, or wireless LAN starts at $600 ~
	Data archiving system	
	Other	
Software	$395~.	
Labor	Installation	
	Use	
Other: Additional costs for power, cell phone provider or wireless LAN provider; all depend on the scale of project.		

4. Limitations	
Life expectancy	30 plus years (Campbell Scientific Inc, has systems that are over 27-year-old and still being used daily)
Power	All data acquisition products designed to run on 12V DC; can also be powered by main line, 110/220V AC.
Environmental conditions	-55C to 85C temperature, low power, rugged design. Must be sealed from direct contact of rain, snow, and condensation.
Data storage/transfer/ processing	Non-volatile data storage up to 4 Giga-byte. Data collection can be manually initiated or automated. Complex processing (rainflow, FFT's, standard deviation, covariance, time of max. or min., etc.) is built into systems eliminating the need for post processing of the data.
Other:	

5. Implementation Needs	
Power source	Battery, AC/DC, solar panel.
Accessibility	Based on how the system is constructed. Data acquistion system can be placed thousnads of feet away from sensors if necessary.
Technical expertise	Programming of the data acquisition system is necessary. Program generators for quick program development and an editor for more complex programming needs are available.
Other:	

6. Availability

All data acquistion equipments are available within 3 to 5 weeks depending upon the quantity ordered; may take longer for more complex system.

7. On-Going or Completed Bridge Related Projects and References

Williamsburg Bridge, New York City, New York.
Monitoring deck performance of three bridges on Montana State Route 243, Saco, Montana.
Confederation Bridge, Prince Edward Island, Nova Scotia, Canada.
Medway Bridge, Kent, England.
Menai Bridge, North Wales.
Several researches at ATLSS Research center at Lehigh University.
Many other projects throughout the world.

References:

• "Strain Gages Monitor Structural Performance," Campbell Scientific, Inc.
• "Lowering the Jams Joyce Bridge at Blackhall Place, Dublin," Campbell Scientific, Inc.
• Many others available (can be found in various literatures).

8. Notes

• CSI was organized in 1974 and manufactures dataloggers, data acquisition systems, and measurement and control products used worldwide in research and industry.
• Additional feasures and possible benefits of CSI's products include: processing for rainflow & level crossing algorithms can accommodate a large number of cycles; onboard, programmable, excitation is provided for ratiometric bridge measurements; systems provide triggered output with pretrigger data capture capability; most sensors and communications options can be used, allowing systems to be customized to meet specific needs; systems can operate in harsh environments; systems can report conditions by calling out to pagers, radios, or phones; systems support long-term, unattended data storage and transfer; pick-and-click software facilitates programming.
• CSI's products have been widely used by many companies for their product bases (e.g., data acquisition system, monitoring system, etc.).

1. General Information

Description of Technology	Fiber optic sensor technology.		
Manufacturer and Contact information	Chen Yang Franz-Brombach-Str. 11-13, D-85345 Erding, Germany	www.chenyang-ism.com Tel: +49 (0) 8122-227-4508 Fax: +49 (0) 8122-227-4509	
Features	Sensor type	Fiber optic sensor (CY-OS 1500 FBG sensor): very low insertion and splicing loss; designed for Micron Optic FBG interrogation equipment and similar detectors; It can be chained with up to 20 sensors in an array for over kilometers distance.	
	Data acquisition, processing, and archiving		
	Communications		
	'Smart' attributes		
	Other	The sensor gratings are directly written on standard single mode fiber (SMF-28 or equivalent) for low attenuation and low splicing loss.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☒ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☒ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☒ Main/secondary cable ☒ Cable anchorage ☒ Anchor rod ☒ Damping system ☒ Strand shoes ☒ Cable bands ☒ Cable enclosures ☐ Other: 2. Movable bridge ☒ Electric brakes ☒ Motors and power ☒ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☐ Crack/fracture ☐ Expansion/contraction ☐ Rotation/torsion ☐ Wear/spalling/scaling/delamination
☐ Section loss ☐ Settlement ☐ Misalignment ☐ Connection failure or deficiencies
☐ Deformation ☐ Wire breakage ☐ Mechanical/electrical malfunction ☐ Impact damage
☐ Debonding ☐ Erosion/scour ☐ Looseness and pounding ☐ Excessive joint closing/opening
☐ Corrosion ☐ Environmental ☐ Other:

Measurement Metric

☒ Strain ☐ Deflection/displacement ☐ Acceleration/vibration ☐ Moisture/humidity level
☒ Temperature ☐ Magnetic field/flux ☐ Electrical voltage/current ☐ Chemical composition
☐ Radar waves ☐ Acoustic waves ☐ Magnetic waves ☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☐ Wind speed/direction ☐ Other:

3. Cost		
Hardware	Sensor	For 1 to 5 pieces: $109.85 per unit. For 6 to 10: $97.5 per unit. For 11 to 50: $81.25 per unit. For larger quantity: upon agreement.
	Data acquisition system	
	Communication system	
	Data archiving system	
	Other	
Software		
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	No official life expectancy. ChenYang guarantee their products for the proof test of CY-OS1500 FBG at 100k spi.
Power	
Environmental conditions	-10°C to 100°C
Data storage/transfer/ processing	
Other:	

5. Implementation Needs	
Power source	
Accessibility	Direct access needed for sensor installation.
Technical expertise	Basic instrumentation skills. Knowledge of dynamics.
Other:	

6. Availability
Approximately 4 weeks.

7. On-Going or Completed Bridge Related Projects and References
Used on many bridge monitoring projects (detail informaiton is not available).

8. Notes
• ChenYang Engineering does research and develops specialty sensors such as magnetoresistive (GMR), magnetoelastic, inductive eddy current and capacitive sensors, computer-controlled precise measuring and testing systems, and special signal processing methods and algorithms. • Other sensors and measurement devices for various applications are also available.

1. General Information

Description of Technology	Real-time 3D GPS monitoring system for real-time deformation monitoring of structures.	
Manufacturer and Contact information	Condor Earth Technologies, Inc. 21663 Brian Lane, Sonora, CA 95370	www.condorearth.com or www.3d-gps.com Tel: (209) 532-0361 or (209) 234-0518 Fax: (209) 532-0773
Features	Sensor type	GPS receivers.
	Data acquisition, processing, and archiving	Condor's 3D Tracker software uses GPS technology to compute 3-dimensional positions in real time for deformation monitoring applications (software can be developed to meet specific requirements).
	Communications	Data from GPS receivers located on the target structure is transferred in real-time via modem, wireless radio or Internet, LAN, etc. to a PC.
	'Smart' attributes	The software provides immediate notification by pager, e-mail, or cell phone when motion thresholds are exceeded (alarm system for each site being monitored).
	Other	Operators can have full remote control over the system from anywhere.

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber: ☒ Plank ☐ Other: ☒ Nailed laminated ☒ Glue-laminated ☒ Prestressed laminated ☒ Stressed timber	
	☒ Concrete: ☒ Reinforced ☐ Other: ☒ Prestressed/post-tensioned	
	☒ Steel: ☒ Grid ☐ Other: ☒ Orthotropic ☒ Buckle plate ☒ Corrugated steel flooring	
	☒ FRP:	
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Girder floor beam/diaphragm system ☒ Tee beam ☒ Box girder ☒ Channel beam ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	
	Secondary Element ☒ Connector and fastener: ☒ Riveted/bolted ☒ Welded ☒ Pin & hanger ☒ Splice ☒ Bracing: ☒ Cross ☒ Lateral ☒ Sway ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	
	Bearing ☒ Fixed ☒ Expansion: ☒ Sliding plate ☒ Roller ☒ Rocker ☒ Pin and link ☒ Elastomeric ☒ Pot ☒ Restraining ☐ Other:	
	Other:	
Substructure	☒ Abutment: ☒ Footing ☐ Other: ☒ Bridge seat ☒ Piles ☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile: ☒ Pier cap ☐ Other: ☒ Shaft ☒ Column/stem ☒ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☐ Main/secondary cable ☐ Cable anchorage ☐ Anchor rod ☐ Damping system ☐ Strand shoes ☐ Cable bands ☐ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:	
	Other:	

Monitoring Interest

☐ Crack/fracture ☐ Expansion/contraction ☒ Rotation/torsion ☐ Wear/spalling/scaling/delamination
☐ Section loss ☒ Settlement ☒ Misalignment ☐ Connection failure or deficiencies
☒ Deformation ☐ Wire breakage ☐ Mechanical/electrical malfunction ☐ Impact damage
☐ Debonding ☐ Erosion/scour ☐ Looseness and pounding ☐ Excessive joint closing/opening
☐ Corrosion ☐ Environmental ☐ Other:

Measurement Metric

☐ Strain ☒ Deflection/displacement ☐ Acceleration/vibration ☐ Moisture/humidity level
☐ Temperature ☐ Magnetic field/flux ☐ Electrical voltage/current ☐ Chemical composition
☐ Radar waves ☐ Acoustic waves ☐ Magnetic waves ☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☐ Wind speed/direction ☐ Other:

3. Cost		
Hardware	Sensor	
	Data acquisition system	
	Communication system	
	Data archiving system	
	Other	
Software		
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	No official life expectancy
Power	110/220V AC. System can be designed to any power supply.
Environmental conditions	
Data storage/transfer/ processing	
Other: System requires: Pentium III or higher; 500MHZ CPU; 256 MB RAM; 9.0 GB SCSI hard drive; Super XGA 1280x1024/High-end 16MB video card; Windows NT Workstation/Windows 2000.	

5. Implementation Needs	
Power source	AD/DC, solar panel.
Accessibility	Direct access needed for system installation. Remote data acquisition.
Technical expertise	Basic electronics and computer skills. Moderate training on how to use the system.
Other:	

6. Availability

Upon agreement (depending on complexity of the system).

7. On-Going or Completed Bridge Related Projects and References

Condor's system has been used on several projects (bridge, dam, building, etc.); No detailed information on bridge monitoring is available.

8. Notes

- Founded in 1983, Condor Earth Technologies, Inc. is a multidisciplinary team of engineers, scientists and technical managers providing earth science consulting services and technologies for a wide range of projects; backgrounds in geotechnical engineering, environmental engineering, planning, permitting, GIS, geology, hydrology, hydrogeology, regulatory compliance, construction materials testing, and surveying/mapping using the latest GPS and geomatic technology tools such as PenMap and 3D Tracker.
- Condor's project support role begins as early as planning and background data collection, and can continue beyond project completion with monitoring and data management services.
- Condor is the first company to provide turn-key systems for 3D monitoring using GPS technology.
- Condor's 3D monitoring systems are based upon differential GPS processing and can provide millimeter accuracy.
- No need to perform additional plotting or processing of the deformation data.

1. General Information

Description of Technology	MICA MOTE wireless smart sensor networking system based on MEMS technologies.	
Manufacturer and Contact information	Crossbow Technology, Inc. 41 Dagget Dr., San Jose, CA 95134	www.xbow.com Tel: (408) 956-3300 Fax: (408) 324-4840
Features	Sensor type	MTS400/420 sensors (includes on-board temperature, humidity, barometric pressure, 2 axis acclerometer). Tiltmeter, acoustic, magnetic and other sensors available. CXTD (digital tilt & acceleration sensor).
	Data acquisition, processing, and archiving	MDA300 data acquisition modules (interfaces directly with a host of external sensors, storing calibration parameters on-board. Compatible with MICA2DOT and TinyOS (TOS) distributed software operating system (radio messaging, sensor measurements and signal processing). Also, GYRO-VIEW software available.
	Communications	Wireless communication with every node as router capability via Multi-channel radio transceiver. Ethernet, Internet.
	'Smart' attributes	Fully programmable, self organizing. Alert can be generated when parameters exceed certain thresholds.
	Other	MICA2 is a third generation mote module used for enabling low-power, wireless, sensor networks. Various systems can be configured using different mote kits, sensor/data acquisition boards, and network interface.

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☒ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☒ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☒ Main/secondary cable ☒ Cable anchorage ☒ Anchor rod ☒ Damping system ☒ Strand shoes ☒ Cable bands ☒ Cable enclosures ☐ Other: 2. Movable bridge ☒ Electric brakes ☒ Motors and power ☒ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☐ Crack/fracture ☒ Expansion/contraction ☒ Rotation/torsion ☐ Wear/spalling/scaling/delamination
☐ Section loss ☒ Settlement ☐ Misalignment ☐ Connection failure or deficiencies
☒ Deformation ☐ Wire breakage ☐ Mechanical/electrical malfunction ☐ Impact damage
☐ Debonding ☐ Erosion/scour ☐ Looseness and pounding ☐ Excessive joint closing/opening
☐ Corrosion ☐ Environmental ☐ Other:

Measurement Metric

☒ Strain ☒ Deflection/displacement ☒ Acceleration/vibration ☒ Moisture/humidity level
☒ Temperature ☐ Magnetic field/flux ☒ Electrical voltage/current ☐ Chemical composition
☐ Radar waves ☒ Acoustic waves ☒ Magnetic waves ☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☐ Wind speed/direction ☐ Other:

3. Cost		
Hardware	Sensor	MTS400: $250 per unit. MTS420: $375 per unit. CTXD: $1,695 per unit
	Data acquisition system	Variable (e.g., MDA300: $275).
	Communication system	Variable
	Data archiving system	Variable
	Other	Additional cost for accessories.
Software	TinyOS: free, available on company website link (www.tinyos.net).	
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	No official life expectancy.
Power	Battery: 2X AA batteries (MICA2), 3V coin cell (MICA2DOT). External Power: 2.7 - 3.3V (MICA2, MICA2DOT), 7 to 30V DC (CXTD).
Environmental conditions	Operating temperature: -10°C to 60°C (MTS), -40°C to 85°C (CXTD).
Data storage/transfer/ processing	Depends on type of products.
Other:	

5. Implementation Needs	
Power source	Battery, DC.
Accessibility	Custom sensor configurations available.
Technical expertise	Basic electronics and instrument handling skills.
Other:	

6. Availability
1-2 weeks

7. On-Going or Completed Bridge Related Projects and References

Golden Gate Bridge, San Francisco, CA.

References:

- High Performance Wireless Research and Education Network (HPWREN), http://hpwren.uscd.edu
- Chung, H.C., Enomoto, M., Loh, K., and Shinozuka, M. "Real Time Visualization of Structural Response through Wireless Communication using MEMS Sensors," Proceedings of SPIE: Testing, Reliability, and Application of Micro- and Nano-Material Systems II, Vol. 5392, pp. 239-246, July 2004.
- Rev, A. "TinyOS Getting Started Guide," Crossbow Technology Inc., San Hose, California, 2003.

8. Notes

- Crossbow Technology is a supplier of inertial sensor systems for various industries and other instrumentation sensors; the company offers full solutions in the wireless sensor networking area.
- Crossbow is the only manufacturer of smart dust wireless sensors.
- Some of features and capabilities of Crossbow products include: Unattended monitoring; Multi-parameter sensing; Low cost, wirelessly networked data acquisition; Threshold-based data aggregation and event triggering; Timely and reliable detection of structural problems.

1. General Information

Description of Technology	Scour monitoring system based on time-domain reflectometry (TDR); for continuous, real-time, dynamic detection and measurement of bridge scour.	
Manufacturer and Contact information	Cold Regions Research and Engineering Laboratory (CRREL) 72 Lyme Rd, Hanover, NH 03755 (US Army Corps of Engineers)	www.crrel.usace.army.mil Tel: (603) 646-4319 Fax: (603) 646-4477
Features	Sensor type	TDR probes developed by CRREL; a number of inexpensive, vertically oriented sensors that are securely anchored into sediments below the maximum expected depth of scour.
	Data acquisition, processing, and archiving	CR10X (manufactured by Campbell Scientific, Inc.) data acquisition system configured the multiplexer to the desired channel. The instrumentation uses 251 points to digitize the refelected wave and corresponding travel distance. The digitized image was read and stored by the CR10 in a local storage module.
	Communications	A computer at CRREL recovered the data daily using a modem integrated into the DAC package.
	'Smart' attributes	
	Other	As a periodic performance check, a portable TDR system was connected to each probe, and the image was recorded on a laptop computer.

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☐ Timber: ☐ Plank ☐ Nailed laminated ☐ Glue-laminated ☐ Prestressed laminated ☐ Stressed timber ☐ Other:	
	☐ Concrete: ☐ Reinforced ☐ Prestressed/post-tensioned ☐ Other:	
	☐ Steel: ☐ Grid ☐ Orthotropic ☐ Buckle plate ☐ Corrugated steel flooring ☐ Other:	
	☐ FRP:	
Superstructure	*Primary Element* ☐ Multi-beam/girder system: ☐ Girder floor beam/diaphragm system ☐ Tee beam ☐ Box girder ☐ Channel beam ☐ Slab ☐ Truss member ☐ Arch element ☐ Other:	
	Secondary Element ☐ Connector and fastener: ☐ Riveted/bolted ☐ Welded ☐ Pin & hanger ☐ Splice ☐ Bracing: ☐ Cross ☐ Lateral ☐ Sway ☐ Diaphragm ☐ Cover plate ☐ Stiffener ☐ Other:	
	Bearing ☐ Fixed ☐ Expansion: ☐ Sliding plate ☐ Roller ☐ Rocker ☐ Pin and link ☐ Elastomeric ☐ Pot ☐ Restraining ☐ Other:	
	Other:	
Substructure	☒ Abutment: ☐ Footing ☐ Bridge seat ☐ Piles ☐ Wall (stem/back/wing) ☒ Other: members subjected to scour.	
	☒ Pier/bent/extended pile: ☐ Pier cap ☐ Shaft ☐ Column/stem ☐ Submerged pile/pile cap/footing ☒ Other: members subjected to scour.	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☐ Tower ☐ Main/secondary cable ☐ Cable anchorage ☐ Anchor rod ☐ Damping system ☐ Strand shoes ☐ Cable bands ☐ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:	
	Other:	

Monitoring Interest

☐ Crack/fracture ☐ Expansion/contraction ☐ Rotation/torsion ☐ Wear/spalling/scaling/delamination
☐ Section loss ☐ Settlement ☐ Misalignment ☐ Connection failure or deficiencies
☐ Deformation ☐ Wire breakage ☐ Mechanical/electrical malfunction ☐ Impact damage
☐ Debonding ☒ Erosion/scour ☐ Looseness and pounding ☐ Excessive joint closing/opening
☐ Corrosion ☐ Environmental ☐ Other:

Measurement Metric

☐ Strain ☒ Deflection/displacement ☐ Acceleration/vibration ☐ Moisture/humidity level
☒ Temperature ☐ Magnetic field/flux ☒ Electrical voltage/current ☐ Chemical composition
☐ Radar waves ☐ Acoustic waves ☐ Magnetic waves ☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☐ Wind speed/direction ☐ Other:

3. Cost		
Hardware	Sensor	
	Data acquisition system	
	Communication system	
	Data archiving system	
	Other	
Software		
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	
Power	
Environmental conditions	
Data storage/transfer/ processing	
Other:	

5. Implementation Needs	
Power source	
Accessibility	
Technical expertise	
Other:	

6. Availability

According to Leonard Zabilansky, an engineer of CRREL, Senera Corporation (www.senera.com) is currently negotiating the rights to the patents; point of contact is Chris Adams (781-907-9403, cadams@senera.com).

7. On-Going or Completed Bridge Related Projects and References

Rt 16 Missouri River Bridge, Montana.
Rt 5 White River Bridge,Vermont.

References:

- Zabilansky, L.J., Ettema, R., Wuebben, J., and Yankielun, L.E. "Survey of river ice influences on Channel Bathymetry along the Fort Peck Reach of the Missouri River, Winter 1998-1999," Technical Report ERDC/CRREL TR-02-14, the US Army Corp of Engineers, September 2002.
- Hains, D., and Zabilansky, L.j. "Laboratory Test of Scour under Ice: Data and Preliminary Results," Technical Report ERDC/CRREL TR-04-0, the US Army Corp of Engineers, April 2004.

8. Notes

- The scour monitoring system was developed to continuously monitor channel changes associated with river ice formation and breakup, as well as with flow rate changes.
- It is capable of tracking, in real time, changes in channel bed elevation through the winter.
- This scour monitoring and detection system is effective even with high energy flow and under ice cover and in debris-infested water; allows unatteded automatic operation; provides all-weather, day-and-night operation; provides high resolution of sour depth; supplies real-time, dynamic data; resets automatically, enabling measurement of multiple erosion/deposition event.

1. General Information

Description of Technology	Advanced high-speed data acquisition and control systems, transducer signal conditioning.		
Manufacturer and Contact information	Daytronic Corporation 2211 Arbor Boulevard, Dayton, Ohio 45439-1521	www.daytronic.com Tel: (937) 293-2566 Fax: (937) 293-2586	
Features	Sensor type	LVDTs, Strain gage load cells, displacement transducers, and others.	
	Data acquisition, processing, and archiving	System 10 data acquisition and control system: capable of a wide range of configurations, from small benchtop data loggers to local area networks that can handle thousands of data points, while monitoring and controlling multiple complex processes simultaneously (data collection, display, archiving, communication and processing).	
	Communications	RS-232/485, GPIB, Modbus, Profibus, and Ethernet. Other wired or wireless communication options (e.g., satellite communication) are available upon request.	
	'Smart' attributes	Real-time, continuous data measurement, control and analysis/computations; alarm triggering function when exceeding predetermined thresholds.	
	Other	5D series signal conditionaer modules: rugged, aluminum casting, self-contained, easily configurable device; serves as a front end for a PC with a 16- or 32-channel A/D card; connects all power and communications lines in a single serial port, and provides luggable screw terminals for all module outputs.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☒ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☒ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☒ Main/secondary cable ☒ Cable anchorage ☒ Anchor rod ☒ Damping system ☒ Strand shoes ☒ Cable bands ☒ Cable enclosures ☐ Other: 2. Movable bridge ☒ Electric brakes ☒ Motors and power ☒ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☒ Crack/fracture ☐ Expansion/contraction ☐ Rotation/torsion ☐ Wear/spalling/scaling/delamination
☐ Section loss ☒ Settlement ☐ Misalignment ☒ Connection failure or deficiencies
☒ Deformation ☐ Wire breakage ☐ Mechanical/electrical malfunction ☒ Impact damage
☐ Debonding ☐ Erosion/scour ☐ Looseness and pounding ☐ Excessive joint closing/opening
☐ Corrosion ☒ Environmental ☐ Other:

Measurement Metric

☒ Strain ☒ Deflection/displacement ☒ Acceleration/vibration ☐ Moisture/humidity level
☒ Temperature ☐ Magnetic field/flux ☒ Electrical voltage/current ☐ Chemical composition
☐ Radar waves ☐ Acoustic waves ☐ Magnetic waves ☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☐ Wind speed/direction ☐ Other:

3. Cost		
Hardware	Sensor	LVDTs: $205~$1,525 per unit. Thermocouples: $250~$365 per unit. Prices are based on sensor capacity.
	Data acquisition system	5D modules: $425 (single channel) ~ System 10: $2500~$250,000 depending on the type and number of input channels (including communication, archiving system and softwares).
	Communication system	
	Data archiving system	
	Other	
Software	System 10 OPC server: $495.	
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	No official life expectancy. Upgradable.
Power	110/220V AC.
Environmental conditions	System 10: -20 to 70°C. 5D modules: -10 to 70°C, 5 to 95% relative huminity, non-condensing.
Data storage/transfer/ processing	
Other:	

5. Implementation Needs	
Power source	AC/DC.
Accessibility	Data can be collecteted either at the site or at a remote location.
Technical expertise	Moderate training on how to use the system.
Other:	

6. Availability
Upon agreement.

7. On-Going or Completed Bridge Related Projects and References
Daytronic's products have been used by Illinois DOT and University of Missouri at Rolla (detailed project information not available).

8. Notes
• Daytronic was founded in 1956 and has specialties in signal conditioning. • The company also offers custom designs and solutions for various application requirements (e.g., testing, system controlling, monitoring, management, etc.).

1. General Information

Description of Technology	Acoustic Emision (AE) structural health monitoring system; capable of measuring crack growth in 'noisy' environment.		
Manufacturer and Contact information	Dunegan Engineering Company, Inc. P.O. Box 1749, San Juan Capistrano CA 92693	www.deci.com Tel: (949) 661-8105 Fax: (949) 661-3723	
Features	Sensor type	Acoustic emision sensors. High/low frequency tranducers.	
	Data acquisition, processing, and archiving	AE SMART 2000 system (expandable to 24 channels) includes Ni-Daq driver software and A/D converter PCMIA or PCI card, DECI-24 ASL software package. It utilizes patened Modal Ratio analysis to separate valid crack growth signals from extraneous noise and to estimate crack depth in real-time.	
	Communications	Direct wire connection.	
	'Smart' attributes	Real-time, continuous crack monitoring. An automatic system, "hold", allows data to only record when the load is present on the bridge.	
	Other	The system eliminates extraneous noise sources before they enter the data base. Each channel can be independently setup.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☒ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☐ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☒ Main/secondary cable ☒ Cable anchorage ☒ Anchor rod ☒ Damping system ☒ Strand shoes ☒ Cable bands ☒ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☒ Crack/fracture	☐ Expansion/contraction	☐ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☐ Section loss	☐ Settlement	☐ Misalignment	☒ Connection failure or deficiencies
☐ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☒ Impact damage
☐ Debonding	☐ Erosion/scour	☒ Looseness and pounding	☐ Excessive joint closing/opening
☐ Corrosion	☐ Environmental	☒ Other: Earthquake study.	

Measurement Metric

☐ Strain	☐ Deflection/displacement	☐ Acceleration/vibration	☐ Moisture/humidity level
☐ Temperature	☐ Magnetic field/flux	☐ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☒ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☐ Other:	

3. Cost

Hardware	Sensor	SE650-PI preamplifier sensor: $485 per unit. SE150-M sensor: $260 per unit. SE375-M sensor: $302 per unit. SE40-Q low frequency transducer: $325 per unit. SE55-R low frequency/high sensitivity sensor: $325 per unit.
	Data acquisition system	DECI 302A: $2,200. AE SMART 2000 system: $9,950.
	Communication system	
	Data archiving system	
	Other	SE1000-HI integral preamplifier: $800. MUX-MODULE: $550. Mux-spliter Mux-Module to hardware connection: $225.
Software	DECI-24 software package for crack growth: $500.	
Labor	Installation	
	Use	
Other: 500J power adaptor: $310. MB-1 Microdot to BNC cable: $80. Twill lead cable for MUX-Module 10 ft long: $60. Model 600 pulser: $650. Model 600B battery pack for pulser: $95.		

4. Limitations

Life expectancy	No official life expectancy.
Power	15V DC.
Environmental conditions	SE1000-HI: -20 to 60°C. SE150-M and 375-M: -50 to 125°C. SE650-P and 40-Q: -50 to 100°C. MUX-MODULE and Model 600 pulser: -50 to 50°C.
Data storage/transfer/ processing	
Other:	

5. Implementation Needs

Power source	DC.
Accessibility	Direct access needed for sensor installation and data acquisition.
Technical expertise	Understanding of acoustic emsion. Moderate training on how to use the system.
Other: User must have a laptop computer with a vacant PCMCIA slot or desktop computer with a vacant PCI slot; Computer should be equipped with Microsoft XP software and Excel; Additional recommended accessory includes a dual channel digital oscilloscope with FFT capability.	

6. Availability

30 days.
Warranty: 1 year.

7. On-Going or Completed Bridge Related Projects and References

Mason Creek Bridge, Canada.
Railroad bridges in Pueblo, Colorado.

References:

- Dunegan, H.L. "Considerations for Selection of Advanced AE Transducers," DECI Report, May 2003.
- Uppal, S., and Dunegan, H.L. "Using Acoustic Emission to Monitor Fatigue Cracks on the Bridge at FAST," Technology Digest, Febrary 2002.
- Dunegan, H.L. "A New Acoustic Emission Technique for Detecting and Locating Growing Cracks in Complex Structures" DECI Publication #0005, May 2000.
- Dunegan, H.L. "Acoustic Emission Monitoring of Fatigue Crack Growth in Bridges," DECI Report, November 1998.

8. Notes

- Founded in 1968, DECI is the first company to produce acoustic emission instrumentation for sale.
- The sytem described in this form is a basic system for monitoring and studying fagigue crack growth, leak detection, tribology studies, bearing monitoring, metal cutting, grinding, polishing, and frequency analysis of AE signals.
- The system can be expandable to 24 channels with a sensor, Mux-Module, and cable for approximately $1,150 per channel added depending on the type of sensor and length of cable between Mux-Modules.

1. General Information

Description of Technology	System solutions for real-time data acquisition and processing for structural health monitoring; remotely records and analyzes all channels in real-time.	
Manufacturer and Contact information	Digitexx Data System, Inc. 145 N. Sierra Madre Blvd. #9, Pasadena, CA 91107	www.digitexx.com Tel: (626) 568-3171 Fax: 626-568-3182
Features	Sensor type	Accelerometer (D110-U). Dititexx system is compatible with most commercially available sensors.
	Data acquisition, processing, and archiving	RTMS-2001RN (16 bit or 24 bit): 32-channel real-time data acquisition and analysis system; manual/event driven triggering; capable of broadcating streaming data, data retrieval and remote tele-control.
	Communications	Monitoring (E-mail, web). Streaming (InternetTCP). Data retrieval (TCP, FTP).
	'Smart' attributes	Real-time, continuous monitoring with alarm triggering capability.
	Other	PDAQ-8: portable data acquisition system offering all the utilities and power needded for field/remote operation.

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☐ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☐ Cover plate ☐ Stiffener ☐ Other:	☐ Riveted/bolted ☒ Cross	☐ Welded ☒ Lateral	☐ Pin & hanger ☒ Sway	☐ Splice	
	Bearing ☐ Fixed ☐ Expansion: ☐ Other:	☐ Sliding plate	☐ Roller	☐ Rocker	☐ Pin and link	☐ Elastomeric ☐ Pot ☐ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☐ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☐ Strand shoes 2. Movable bridge ☐ Electric brakes	☐ Main/secondary cable ☐ Cable bands ☐ Motors and power	☐ Cable anchorage ☐ Cable enclosures ☐ Operating machinery and equipment	☐ Anchor rod ☐ Other:	☐ Damping system ☐ Other:	
	Other:					

Monitoring Interest

☐ Crack/fracture	☐ Expansion/contraction	☐ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☐ Section loss	☒ Settlement	☐ Misalignment	☐ Connection failure or deficiencies
☒ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☒ Impact damage
☐ Debonding	☐ Erosion/scour	☐ Looseness and pounding	☐ Excessive joint closing/opening
☐ Corrosion	☐ Environmental	☒ Other: Seismic activity.	

Measurement Metric

☐ Strain	☒ Deflection/displacement	☒ Acceleration/vibration	☐ Moisture/humidity level
☒ Temperature	☐ Magnetic field/flux	☐ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☐ Other:	

3. Cost		
Hardware	Sensor	D110-U accelerometer: $800 per unit. Other sensors also available (displacement, strain, fiber optic sensors, etc).
	Data acquisition system	RTMS-2001RN: $55,000 (16 bit) and $75,000 (24 bit).
	Communication system	Included.
	Data archiving system	Included.
	Other	PDAQ-8 portable data acquisition system: $12,500 including a laptop.
Software	RTMS-2000RN remote client software: included with the system.	
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	No official life expectancy. Systems can be upgradable over time.
Power	D110-U: ±12V DC, 9mA. RTMS-2001RN: 110/220V AC w/UPS. PDAQ-8: 12V 2AmpH (internal), 12V (external), 110/220V AC.
Environmental conditions	D110-U: -40°C to 85°C. RTMS-2001RN, PDAQ-8: 0 to 50°C.
Data storage/transfer/ processing	The system has a sampling rate of up to 1,000 samples per second per channel.
Other:	

5. Implementation Needs	
Power source	AC/DC.
Accessibility	Direct access needed for system installation. Remote data acquisition and monitoring.
Technical expertise	Engineering background. Moderate training on how to use the system.
Other:	

6. Availability

5 to 8 weeks.

7. On-Going or Completed Bridge Related Projects and References

Vincent Thomas Bridge, CA.

Reference:

• Radulescu, D.C., Radulescu, C., and Sereci, A.M. "Structural Health Monitoring 24/7 Broadcating System," Proceedings of the 1st International Conference on Structural Health Monitoring and Intelligent Infrastructure, Tokyo, Japan, November 13-15, 2003.

8. Notes

- Digitexx offers system solutions for a central Monitoring for National arrays and regional sub-networks and distributed information data center; the company's service and consulting includes training, calibration, maintenance, data analysis, data reporting, data validation, project layout, technical proposal assistance, etc.
- Additional features of Digitexx products include: real-time inter-story drift hysteresis loops and drift ratio; real-time response spectrum, transfer function, and FFT; On-demand and scheduled remote recording for statistical analysis studies.

1. General Information

Description of Technology	Cable force measurement devices and technologies for determination of forces and tensions in the prestressed concrete components.	
Manufacturer and Contact information	Division Projstar Monitoring Group International Nad Dunajom 50, 841 04 Bratislava 4, Slovakia, Europe	www.dynamag.sk Tel: +421 2 654 22 432 Fax: +421 2 654 22 432
Features	Sensor type	Single coil, double coil, multistrand, and integrated multistrand sensors. Elastomagnetic (EM) sensors.
	Data acquisition, processing, and archiving	NT404 connected together via RS262 or RS485 interface for remote control. Up to 64 channels with MX416 multiplexors. Dynamag NT404A Basic Software (simple user interface for remote control, and manual/automatic measurement).
	Communications	Direct connection or remote control via Internet.
	'Smart' attributes	Temporary or continuous stress or force measurement and time-dependant changes in stressed steel, wire, and cable after anchoring with accuracy of ± 2%.
	Other	Prestressed wires or cables are a direct part of the sensors; magnetoelastic method is a direct measurement method (measuring changes of material magnetic properties, dependent of mechanical stress in material).

2. Applicability

Bridge Type

☐ Slab ☐ Girder/Deck ☐ Truss ☐ Arch
☐ Rigid Frame ☒ Suspension ☒ Cable-stayed ☐ Vertical lift
☐ Swing ☐ Bascule ☐ Other:

Bridge Component

Deck	☐ Timber: ☐ Plank ☐ Nailed laminated ☐ Glue-laminated ☐ Prestressed laminated ☐ Stressed timber ☐ Other:	
	☒ Concrete: ☐ Reinforced ☒ Prestressed/post-tensioned ☐ Other:	
	☐ Steel: ☐ Grid ☐ Orthotropic ☐ Buckle plate ☐ Corrugated steel flooring ☐ Other:	
	☐ FRP:	
Superstructure	*Primary Element* ☐ Multi-beam/girder system: ☐ Girder floor beam/diaphragm system ☐ Tee beam ☐ Box girder ☐ Channel beam ☐ Slab ☐ Truss member ☐ Arch element ☒ Other: Prestressed or post-tensioned components	
	Secondary Element ☐ Connector and fastener: ☐ Riveted/bolted ☐ Welded ☐ Pin & hanger ☐ Splice ☐ Bracing: ☐ Cross ☐ Lateral ☐ Sway ☐ Diaphragm ☐ Cover plate ☐ Stiffener ☐ Other:	
	Bearing ☐ Fixed ☐ Expansion: ☐ Sliding plate ☐ Roller ☐ Rocker ☐ Pin and link ☐ Elastomeric ☐ Pot ☐ Restraining ☐ Other:	
	Other:	
Substructure	☐ Abutment: ☐ Footing ☐ Bridge seat ☐ Piles ☐ Wall (stem/back/wing) ☐ Other:	
	☐ Pier/bent/extended pile: ☐ Pier cap ☐ Shaft ☐ Column/stem ☐ Submerged pile/pile cap/footing ☐ Other:	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☐ Tower ☒ Main/secondary cable ☐ Cable anchorage ☐ Anchor rod ☐ Damping system ☐ Strand shoes ☐ Cable bands ☐ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:	
	Other:	

Monitoring Interest

☐ Crack/fracture ☐ Expansion/contraction ☐ Rotation/torsion ☐ Wear/spalling/scaling/delamination
☐ Section loss ☐ Settlement ☐ Misalignment ☐ Connection failure or deficiencies
☐ Deformation ☒ Wire breakage ☐ Mechanical/electrical malfunction ☐ Impact damage
☐ Debonding ☐ Erosion/scour ☐ Looseness and pounding ☐ Excessive joint closing/opening
☐ Corrosion ☐ Environmental ☒ Other: Changes in stress or force

Measurement Metric

☐ Strain ☐ Deflection/displacement ☐ Acceleration/vibration ☐ Moisture/humidity level
☐ Temperature ☒ Magnetic field/flux ☐ Electrical voltage/current ☐ Chemical composition
☐ Radar waves ☐ Acoustic waves ☒ Magnetic waves ☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☐ Wind speed/direction ☐ Other:

3. Cost		
Hardware	Sensor	Single coil sensor: $36.30 (monostrand) ~ $605 (CCA 200mm diameter strand); €1.00 = $1.21. Multistrand sensor: price begins from Number of strands x $36.30. Special kind of sensors (Elastomagetic sensor, Double coil sensors, etc.): determined by specification needs.
	Data acquisition system	NT404 (4-channel with RS-232 interface, basic software without power supply): $7,865.
	Communication system	
	Data archiving system	
	Other	Multiplexers: price begins from $605 for 8-channel multiplexer.
Software	Included.	
Labor	Installation	
	Use	
Other: Cabling, calibration, customer specific software, consulting, customer support is not included in prices (these are fee-based upon agreement).		

4. Limitations	
Life expectancy	No official life expectancy.
Power	24V/1A DC adapter/battery.
Environmental conditions	-10 to 60°C.
Data storage/transfer/ processing	
Other: Maximum distance of 800m between measuring units. Maximum distance of 200m from the EM sensor through the multiplexor to the measuring unit. It can be used for ferromagnetic materials only.	

5. Implementation Needs	
Power source	Battery, AC/DC.
Accessibility	Direct access needed for sensor installation and data acquisition (remote monitoring optional).
Technical expertise	Minimal training. Engineereing support is available.
Other: It is necessary to calibrate sensors for new materials by measuring its magnetic characteristics.	

6. Availability

Availability of sensors depends on type and size of sensors: 2 to 3 weeks for monostrands and small amount (<100 pcs); 4 to 5 weeks for bigger sensors; up to 8 weeks for NT404A and multiplexer.

7. On-Going or Completed Bridge Related Projects and References

Ashidagawa Cable Stayed Bridge, Japan, 2002.
Second Yangtze River Bridge at Hanjing, China, 2001.
Jiangyin bridge over the Yangtzw River, China, 1999.
LaFranconi Bridge over Danube, Bratislava, Slovak Republic, 1992.
Cable Stayed Bridge in Podebrady, Czech Republic, 1990
Cable Stayed Bridge in Tabor, Czech Republic, 1989.

Several references available on company website.

8. Notes

- Dynamag has about 15 years of experience in monitoring bridges.
- Dynamag's products are mainly for determination of forces and tension in prestressed concrete components.
- The company uses a contact-free measurement method for force distribution in the pre- or post-stressed steel core both during their construction and throughout the entire lifetime.

1. General Information

Description of Technology	Piezoelectric sensing technology.		
Manufacturer and Contact information	DYTRAN Instruments Inc. 21592 Marilla St., Chatsworth, California 91311	www.dytran.com Tel: (818) 700-7818 Fax: (818) 700-7880	
Features	Sensor type	Accelerometers: high sensitivity sensors that can be used for low amplitude vibration measurements with various ranges, sensitivities, and polarities. Model 3191A accelerometer: 5V/g, top MIL-C-5015 2-pin connector, low noise, 1/4-28 mounting hole, accepts Immersion Proof boot.	
	Data acquisition, processing, and archiving	Data acquisition system for Dytran's accelerometer are provided by TMI Inc. (www.tmirep.com).	
	Communications		
	'Smart' attributes		
	Other		

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☐ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☐ Cover plate ☐ Stiffener ☐ Other:	☐ Riveted/bolted ☒ Cross	☐ Welded ☒ Lateral	☐ Pin & hanger ☒ Sway	☐ Splice	
	Bearing ☐ Fixed ☐ Expansion: ☐ Other:	☐ Sliding plate	☐ Roller	☐ Rocker	☐ Pin and link	☐ Elastomeric ☐ Pot ☐ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☐ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☐ Tower ☐ Main/secondary cable ☐ Cable anchorage ☐ Anchor rod ☐ Damping system ☐ Strand shoes ☐ Cable bands ☐ Cable enclosures ☐ Other: 2. Movable bridge ☒ Electric brakes ☒ Motors and power ☒ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☒ Crack/fracture	☐ Expansion/contraction	☐ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☐ Section loss	☐ Settlement	☐ Misalignment	☐ Connection failure or deficiencies
☐ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☒ Impact damage
☐ Debonding	☐ Erosion/scour	☐ Looseness and pounding	☐ Excessive joint closing/opening
☐ Corrosion	☐ Environmental	☒ Other: Seismic activity.	

Measurement Metric

☐ Strain	☐ Deflection/displacement	☒ Acceleration/vibration	☐ Moisture/humidity level
☐ Temperature	☐ Magnetic field/flux	☐ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☐ Other:	

3. Cost		
Hardware	Sensor	Model 3191A accelerometer: $595 per unit.
	Data acquisition system	
	Communication system	
	Data archiving system	
	Other	
Software		
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	No official life expectancy.
Power	Supply current: 2 to 20 mA (for Model 3191A). Compliance voltage range: 18 to 30V DC.
Environmental conditions	Temperature range: -60 to 50°F (for Model 3191A). Maximum vibration/Shock: 50/100 g's/g's Peak. Coefficient of thermal sensitivity: 0.03%/°F.
Data storage/transfer/ processing	Frequency range: 0.1 to 1000 Hz. Sensitivity: 5 Volts/g (for Model 3191A), 10 Volts/g (for Model 3191A1).
Other: For Model 3191A: Discharge time constant 4.8 second; Measured at 100 Hz, 1g RMS (or 0.5g RMS) per ISA RP 37.2. Applying power without current limiting to 20 mA maximum may destroy integral IC amplifier.	

5. Implementation Needs	
Power source	DC.
Accessibility	Direct access needed for sensor installation.
Technical expertise	Basic instrumentation skills.
Other:	

6. Availability
1 week.

7. On-Going or Completed Bridge Related Projects and References
Information not available.

8. Notes
• Dytran was founded in 1980 and provides NIST traceable calibrations for almost all single axis piezoelectric type accelerometers. • Calibrations are performed in accordance with MIL-STD-45662A, ANSI/NCSL Z540-1-1994, ISO 10012-1. • The company offers repair service for any Dytran manufactured sensor within a two year period from the date of manufacture.

1. General Information

Description of Technology	Instruments that supply seismic and strong motion data; structural monitoring, earthquake engineering, seismic research, and testing applications.		
Manufacturer and Contact information	EENTEC 625 N. Euclid Ave., Suite 404, St. Louis, MO 63108	www.eentec.com Tel: (314) 454-9977 Fax: (314) 454-9979	
Features	Sensor type	Force Balanced Servo Accelerometer (EA-120): low noise, high dynamic range, in a frequency band of DC to 50 Hz; suited for strong motion monitoring applications; available in external, internal, or borehole configurations.	
	Data acquisition, processing, and archiving	DAS-6102 digital recorder: a portable, rugged, ultra low power, high-performance, versatile 22-bit resolution digital seismic recording system; 4 to 32 channels; all channels operate synchronously up to 2,000 samples per second; multiple trigger passband pre-filters; analog and digital alias filtering; 112B dynamic range.	
	Communications	Data is retrieved by removal of the PC compatible compact hard drive, or through dial up telephone access (internal modem optional), or via LAN (Ethernet card optional).	
	'Smart' attributes	Real-time waveform display; operates in both trigger and continuous mode.	
	Other	DAS-6102 includes a GPS receiver and antenna and "Smart Timing" software, allowing the user to select the timing accuracy, which will automatically control and minimize the GPS cycling times.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☐ Multi-beam/girder system: ☒ Slab ☐ Truss member ☐ Arch element ☐ Other:	☐ Girder floor beam/diaphragm system	☐ Tee beam	☐ Box girder	☐ Channel beam	
	Secondary Element ☐ Connector and fastener: ☐ Bracing: ☐ Diaphragm ☐ Cover plate ☐ Stiffener ☐ Other:	☐ Riveted/bolted ☐ Cross	☐ Welded ☐ Lateral	☐ Pin & hanger ☐ Sway	☐ Splice	
	Bearing ☐ Fixed ☐ Expansion: ☐ Other:	☐ Sliding plate	☐ Roller	☐ Rocker	☐ Pin and link	☐ Elastomeric ☐ Pot ☐ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☐ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☐ Shaft	☐ Column/stem	☐ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☐ Strand shoes 2. Movable bridge ☐ Electric brakes	☐ Main/secondary cable ☐ Cable bands ☐ Motors and power	☐ Cable anchorage ☐ Cable enclosures ☐ Operating machinery and equipment	☐ Anchor rod ☐ Other:	☐ Damping system ☐ Other:	
	Other:					

Monitoring Interest

☐ Crack/fracture	☐ Expansion/contraction	☐ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☐ Section loss	☐ Settlement	☐ Misalignment	☐ Connection failure or deficiencies
☐ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☐ Impact damage
☐ Debonding	☐ Erosion/scour	☐ Looseness and pounding	☐ Excessive joint closing/opening
☐ Corrosion	☐ Environmental	☒ Other: Seismic activity.	

Measurement Metric

☐ Strain	☐ Deflection/displacement	☒ Acceleration/vibration	☐ Moisture/humidity level
☐ Temperature	☐ Magnetic field/flux	☐ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☐ Other:	

3. Cost		
Hardware	Sensor	$2,850 for three-component EA-120's with differential output for long sensor runs.
	Data acquisition system	Approximately $16,000 for a 32-channel DAS for eleven three-component instruments.
	Communication system	Need to add approximately $1,500 for LAN, internal modem, and external battery pack. Approximately $4,000 for wireless LAN.
	Data archiving system	
	Other	
Software		
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	No official life expectancy.
Power	EA-120: ±12V typ. others optional. DAS-6102: 7 to 16V DC.
Environmental conditions	EA-120: -10° to 75° C, 95% relative humidity. DAS-6102: -10 to 50°C, 100% relative humidity (built-in automatic heater for optional hard disk).
Data storage/transfer/ processing	DAS-6102: a standard 10Gb removable hard disk is included, with optional disk capacities to to 32Gb. Data Formats: Mini-SEED w/Steim-2 compression up to x6 CSS 3.0; long integer; separate data description in ASCII.
Other: EA-120: Dynamic Range of 128 dB ± 5V or 135 dB ± 10V.	

5. Implementation Needs	
Power source	Battery, DC.
Accessibility	Direct access needed for system installation and data acquisition (optional remote data acquisition, access and control).
Technical expertise	Minimal training.
Other:	

6. Availability
120 days.

7. On-Going or Completed Bridge Related Projects and References

Bridge monitoring project by Central Earthquake Research Institute (eentec supplied 120 channels of EA-120 accelerometers); detailed information not available.

Reference:

• Trifunac, M.D., and Todorovska, M.I. "A Note on the Useable Dynamic Range of Accelerographs Recording Translations," Soil Dynamics and Earthquake Engineering, 2001.

8. Notes

- EENTEC provides products for structural monitoring, earthquake engineering, and seismic research.
- The integrated display and keyboard allows for easy setup in the field and real time viewing of up to 3 waveforms.
- For large permanent installations, DAS product line includes multi-channel PC based or rack mounted systems up to 32 channels (Models DAS-6102-PC or -I).
- Many other products (other than EA-120 and DAS-6102) are available.
- EENTEC offers customized products to meet other application requirements.

1. General Information

Description of Technology	Instrumentation and data measuring devices for continuous monitoring.	
Manufacturer and Contact information	Encardio-rite Electronics Private Ltd. A-7, Industrial Estate, Talkatora Road, Lucknow-226011, UP, India	www.encardio.com Tel: +91-522-2661044, 2661040 Fax: +91-522-2661043
Features	Sensor type	Vibrating wire strain gage, potentiometer, accelerometer, LVDT, tiltmeter, displacement sensor, temperature probe, and others.
	Data acquisition, processing, and archiving	EDAS-10 automatic data acquisition system (suitable for 119 channels consisting of CR-10X datalogger, ESP-216 surge protector, ER 416 16 channel multiplexer, AVW4 V/W interface); Multiple analog, digital, and pulse counting channels (expandable with peripherals); Measurement and logical control functions (measure and/or control virtually any device); Internal data processing (math functions, max., min., avg., worst case, etc.).
	Communications	With an appropriate communication link, PC208W provides two-way communication between EDAS-10 dataloggers and IBM compatible computers. (telephone, satellite, PCMCIA cards, RF, Internet, Ethernet).
	'Smart' attributes	Autonomous, continuous monitoring system capable of alerting responsible officials in case of approaching danger (i.e., data limits).
	Other	EDAS-10 data acquisition system can read virtually any sensor. PC 208W datalogger support software allows telecommunications, programming and basic data processing functions.

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☒ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☐ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☒ Main/secondary cable ☒ Cable anchorage ☒ Anchor rod ☒ Damping system ☒ Strand shoes ☒ Cable bands ☒ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☒ Crack/fracture ☒ Expansion/contraction ☒ Rotation/torsion ☐ Wear/spalling/scaling/delamination
☐ Section loss ☒ Settlement ☐ Misalignment ☐ Connection failure or deficiencies
☒ Deformation ☐ Wire breakage ☐ Mechanical/electrical malfunction ☒ Impact damage
☐ Debonding ☐ Erosion/scour ☐ Looseness and pounding ☐ Excessive joint closing/opening
☐ Corrosion ☒ Environmental ☐ Other:

Measurement Metric

☒ Strain ☒ Deflection/displacement ☒ Acceleration/vibration ☐ Moisture/humidity level
☒ Temperature ☐ Magnetic field/flux ☒ Electrical voltage/current ☐ Chemical composition
☐ Radar waves ☐ Acoustic waves ☐ Magnetic waves ☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☐ Wind speed/direction ☐ Other:

3. Cost		
Hardware	Sensor	Strain gages (embeddable, weldable) with standard 1m cable: $50~$55 per unit. Displacement sensor: $280~$290 per unit. Displacement transducer: $220 per unit. Piezometer: $160 per unit.
	Data acquisition system	EDAS-10: priced based on specification. EDI-51V digital read out data logger: $1,500.
	Communication system	
	Data archiving system	
	Other	Price of automatic data acquisition system depends on number of channels required and type of sensors connedted, etc.
Software		
Labor	Installation	
	Use	
Other: Extensometer (bore hle) and accessories: $700~$1,125 per set		

4. Limitations	
Life expectancy	20 years plus (for wire vibrating sensors). 10 years plus (for automatic data acquisition system; without update or replace of hardware components).
Power	110/220V AC. 9.6 to 16V batteries.
Environmental conditions	-25°C to 50°C.
Data storage/transfer/ processing	Internal Data memory: Storage capacity from 20K to 2M data points; expandable with peripherals.
Other:	

5. Implementation Needs	
Power source	Any 12V battery can be connected as the primary source. Several power supply options are available. An internal type CR2430 lithium battery with a capacity of 270 mAh is provided for clock and RAM backup.
Accessibility	Direct access needed for sensor installation and data acquisition (optional remote data acquisition and control).
Technical expertise	Engineeering background. Moderate training on how to use the system.
Other: The EDAS-10 requires a suitable PC for configuration and downloading programs and retreival of logged data. The PC has to be provided by the user. Any PC with a spare RS-232 serial communications port running Microsoft Windows 98SE/Me/NT4.0/2000 or later operating system is sufficient.	

6. Availability

Normally 2 to 3 weeks.

7. On-Going or Completed Bridge Related Projects and References

Marmada Bridge, Bharuch, Gujarat, India.
Pasir Panjang Expressway LTA C3223, Singapore.

8. Notes

- Encardio-rite, an ISO-9001 certificated organization, was incorporated in 1966 with the main objective of developing, manufacturing and marketing instruments involving high technology; specialties in geotechnical, geophysical, ground water & structural instruments and load cells, scales & weighing systems.
- Due to rapid technological advances and high rate of obsolescense in electronics and computer hardware and software, it may be difficult to give back-up support after about ten years of usage.
- Other features of Encardio's monitoring system include: Precision measurement (analog resolution to 0.66 microvolt); Programmable scan rates (from few times per second to once every few hours); Low power consumption (typically less than 50 mA during measurement); Internal real-time clock (time stamped data); Multiple methods of Data retrieval (storage modules, direct to computer, telephone, satellite, PCMCIA cards, RF, etc.).

1. General Information

Description of Technology	Piezoelectric sensors, accelerometers, force transducers, and MEMS technologies.	
Manufacturer and Contact information	Endevco Corporation 30700 Rancho Viejo Road, San Juan Capistrano, CA 92675	www.endevco.com Tel: (800) 982-6732 or (949) 493-8181 Fax: (949) 661-7231
Features	Sensor type	Piezoelectric accelerometers, force transducers, temperature sensors, wireless sensors and many others.
	Data acquisition, processing, and archiving	
	Communications	
	'Smart' attributes	
	Other	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber: ☒ Plank ☐ Other: ☒ Nailed laminated ☒ Glue-laminated ☒ Prestressed laminated ☒ Stressed timber	
	☒ Concrete: ☒ Reinforced ☐ Other: ☒ Prestressed/post-tensioned	
	☒ Steel: ☒ Grid ☐ Other: ☒ Orthotropic ☒ Buckle plate ☒ Corrugated steel flooring	
	☒ FRP:	
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Girder floor beam/diaphragm system ☒ Tee beam ☒ Box girder ☒ Channel beam ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	
	Secondary Element ☒ Connector and fastener: ☒ Riveted/bolted ☒ Welded ☒ Pin & hanger ☒ Splice ☒ Bracing: ☒ Cross ☒ Lateral ☒ Sway ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	
	Bearing ☒ Fixed ☒ Expansion: ☒ Sliding plate ☒ Roller ☒ Rocker ☒ Pin and link ☒ Elastomeric ☒ Pot ☒ Restraining ☐ Other:	
	Other:	
Substructure	☒ Abutment: ☒ Footing ☐ Other: ☒ Bridge seat ☒ Piles ☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile: ☒ Pier cap ☐ Other: ☒ Shaft ☒ Column/stem ☒ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☒ Main/secondary cable ☒ Cable anchorage ☒ Anchor rod ☒ Damping system ☒ Strand shoes ☒ Cable bands ☒ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☒ Motors and power ☒ Operating machinery and equipment ☐ Other:	
	Other:	

Monitoring Interest

☐ Crack/fracture ☐ Expansion/contraction ☐ Rotation/torsion ☐ Wear/spalling/scaling/delamination
☐ Section loss ☐ Settlement ☐ Misalignment ☐ Connection failure or deficiencies
☐ Deformation ☐ Wire breakage ☐ Mechanical/electrical malfunction ☐ Impact damage
☐ Debonding ☐ Erosion/scour ☐ Looseness and pounding ☐ Excessive joint closing/opening
☐ Corrosion ☐ Environmental ☐ Other:

Measurement Metric

☐ Strain ☐ Deflection/displacement ☒ Acceleration/vibration ☐ Moisture/humidity level
☒ Temperature ☐ Magnetic field/flux ☒ Electrical voltage/current ☐ Chemical composition
☐ Radar waves ☐ Acoustic waves ☐ Magnetic waves ☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☐ Wind speed/direction ☐ Other:

3. Cost		
Hardware	Sensor	$350~$1,380 depending on sensor specification and capacity.
	Data acquisition system	
	Communication system	
	Data archiving system	
	Other	
Software		
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	No official life expectancy.
Power	
Environmental conditions	-55 to 177°C for general purpose piezoelectric accelerometers.
Data storage/transfer/ processing	
Other:	

5. Implementation Needs	
Power source	
Accessibility	Direct access needed for sensor installation.
Technical expertise	Basic instrumentation skills.
Other:	

6. Availability

2 to 5 weeks for standard products.

7. On-Going or Completed Bridge Related Projects and References

Detailed bridge monitoring information not available.
Numerous technical papers are available on company website.

8. Notes

- ENDEVCO has been a FAA Parts Manufacturing Approved facility since 1980, and became ISO 9001 certified in 1994.
- ENDEVCO offers a comprehensive line of piezoelectric, variable capacitance, piezoresistive, ISOTRON®, and servo force balance accelerometers; high accuracy, wide-band frequency and dynamic response, small size, light weight and ease of installation.

1. General Information

Description of Technology	IntelliRock concrete maturity and temperature logging system: in-situ, real-time concrete strength and associated temperature measuring.		
Manufacturer and Contact information	Engius 1414 S. Sangre Road, IDC Building, Stillwater, Oklahoma 74074	www.intellirock.com Tel: (866) 636-4487 Fax: (866) 277-8369	
Features	Sensor type	Concrete maturity and temperature profiling system; embedded microprocessor and high-precision temperature sensor in place of the external recording devices and thermocouples used by other systems.	
	Data acquisition, processing, and archiving	A single hand-held reader can control and access multiple embedded sensors. Up to 200 sets of logger data can be downloaded into the reader. Intellirock software provides a interface to download maturity data from the handheld reader. Logger automatically logs temperature history and calculates current maturity. The reader does not need to be connected for the logger to continue logging data.	
	Communications	Partially embedded two-wire communication interface between logger and reader. Standard cable (normally 4 ft; up to 100 ft).	
	'Smart' attributes		
	Other	LGR-01 concrete maturity logger can be embedded directly into a concrete structure; measures, processes, and stores maturity and temperature data within the concrete. TPL-01 can record up to 28 days of temperature profile.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☐ Timber:	☐ Plank ☐ Other:	☐ Nailed laminated	☐ Glue-laminated	☐ Prestressed laminated	☐ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☐ Steel:	☐ Grid ☐ Other:	☐ Orthotropic	☐ Buckle plate	☐ Corrugated steel flooring	
	☐ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☐ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☐ Cover plate ☐ Stiffener ☐ Other:	☐ Riveted/bolted ☒ Cross	☐ Welded ☒ Lateral	☐ Pin & hanger ☒ Sway	☐ Splice	
	Bearing ☐ Fixed ☐ Expansion: ☐ Other:	☐ Sliding plate	☐ Roller	☐ Rocker	☐ Pin and link	☐ Elastomeric ☐ Pot ☐ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☐ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☐ Strand shoes 2. Movable bridge ☐ Electric brakes	☐ Main/secondary cable ☐ Cable bands ☐ Motors and power	☐ Cable anchorage ☐ Cable enclosures ☐ Operating machinery and equipment	☐ Anchor rod ☐ Other:	☐ Damping system ☐ Other:	
	Other:					

Monitoring Interest

☐ Crack/fracture	☐ Expansion/contraction	☐ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☐ Section loss	☐ Settlement	☐ Misalignment	☐ Connection failure or deficiencies
☐ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☐ Impact damage
☐ Debonding	☐ Erosion/scour	☐ Looseness and pounding	☐ Excessive joint closing/opening
☐ Corrosion	☐ Environmental	☒ Other: Concrete maturity and strength.	

Measurement Metric

☐ Strain	☐ Deflection/displacement	☐ Acceleration/vibration	☐ Moisture/humidity level
☒ Temperature	☐ Magnetic field/flux	☒ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☐ Other:	

3. Cost		
Hardware	Sensor	
	Data acquisition system	
	Communication system	
	Data archiving system	
	Other	
Software		
Labor	Installation	
	Use	
Other: According to Pam Culbertson, project engineer of McCarthy Construction, five months of their cost for intelliRock system was around $3,500.		

4. Limitations	
Life expectancy	No official life expectancy.
Power	Battery: 3 months of logging battery life; 5 years of battery shelf life.
Environmental conditions	-18 to 85°C.
Data storage/transfer/ processing	LGR-01: temperature and maturity at Start, 4 hrs, 12 hrs, 1 day, 2 days, 3 days, 4 days, 5 days, 6 days, and 7 days TPL-01: temperature at start, every 2 hours on days 1 to 3, every 4 hours on days 4 to 6, every 12 hours on days 7 to 28.
Other: Temperature accuracy of ±1°C.	

5. Implementation Needs	
Power source	Battery.
Accessibility	Direct access needed for data collection.
Technical expertise	Minimal training.
Other: Intellirock software runs under Microsoft Windows 95 or newer.	

6. Availability

Upon agreement.

7. On-Going or Completed Bridge Related Projects and References

• I-40 Webbers Falls Bridge, Oklahoma.

References:

• "Method of Testing the Strength of Portland Cement Concrete Using the Maturity Method," Iowa Department of Transportation, Octorber 29, 2002.
• Other case studies and references are available on company website (Since the introduction of intelliRock in 2002, 26 Departments of Transportation and projects in 31 states have used the intelliRock system on projects).

8. Notes

• The intelliRock concrete maturity and temperature profiling system was introduced in May 2002. Since its introduction, 26 Departments of Transportation and projects (where early concrete strength or temperature profiling are critical) in 31 states have used the intelliRock system.
• Logger data is downloaded to the reader; the data stored in the reader is then downloaded to a PC. From the PC, data files can be generated and exported to Excel or other spreadsheet or word-processing software.
• Maturity technique: ASTM C 1074 (Nurse-Saul method).
• Intellirock system is rugged and can operate continuously with no permanently affixed external devices.

1. General Information

Description of Technology	Fiber Bragg Grating (FBG) Sensing technology; system includes interrogation instrument, various sensor heads, installation guide, and technical consulting.		
Manufacturer and Contact information	Fiberpro 59-4 Jang-dong, Yusong-gu, Daejeon, 305-343, Korea	www.fiberpro.com Tel: +82-42-360-0030 Fax: +82-42-360-0040	
Features	Sensor type	FBG sensors, Strain gages, temperature gages, accelerometers, inclinometers and others.	
	Data acquisition, processing, and archiving	FBERPRO's FBG interrogation system was developed for the purpose of providing fast and accurate multi-wavelength analysis for FBG sensor systems; it has a modular structure main-frame, a laser module, and sensor modules; the laser module is based on a patented wavelength swept fiber laser; compatible with various types of sensor heads; system can be expended later by adding optional modules.	
	Communications	Direct wire connection. Ethernet or Internet.	
	'Smart' attributes	Autonomous flaw detecting sytem; compatible with various sensor heads; capable of measuring more than 100 sensors simultaneously.	
	Other	Measurement results are proessed, displayed and stored in users's PC installed with drive software; high measurement speed enables real-time analysis.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☒ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☒ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☒ Main/secondary cable ☒ Cable anchorage ☒ Anchor rod ☒ Damping system ☒ Strand shoes ☒ Cable bands ☒ Cable enclosures ☐ Other: 2. Movable bridge ☒ Electric brakes ☒ Motors and power ☒ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☒ Crack/fracture ☐ Expansion/contraction ☒ Rotation/torsion ☐ Wear/spalling/scaling/delamination
☐ Section loss ☐ Settlement ☐ Misalignment ☐ Connection failure or deficiencies
☒ Deformation ☐ Wire breakage ☐ Mechanical/electrical malfunction ☒ Impact damage
☐ Debonding ☐ Erosion/scour ☐ Looseness and pounding ☐ Excessive joint closing/opening
☐ Corrosion ☐ Environmental ☐ Other:

Measurement Metric

☒ Strain ☐ Deflection/displacement ☒ Acceleration/vibration ☐ Moisture/humidity level
☒ Temperature ☐ Magnetic field/flux ☐ Electrical voltage/current ☐ Chemical composition
☐ Radar waves ☐ Acoustic waves ☐ Magnetic waves ☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☐ Wind speed/direction ☐ Other:

3. Cost		
Hardware	Sensor	$100~$1,000 per unit depending on sensor specification and capacity.
	Data acquisition system	Approximately $35,000; subjected to vary depending on user's requirement.
	Communication system	
	Data archiving system	
	Other	
Software	Included.	
Labor	Installation	
	Use	$3,000/year including maintenance.
Other:		

4. Limitations	
Life expectancy	15 years plus.
Power	110/220V AC 50-60 Hz.
Environmental conditions	0 to 40°C for instrument (without air conditioning). -40°C to 80°C for sensor.
Data storage/transfer/ processing	Measurement speed up to 200 Hz for each sensor. USB, serial interface with PC.
Other:	

5. Implementation Needs	
Power source	AC.
Accessibility	Direct access needed for sensor installation and data acquisition (optional remote data acquisition and control).
Technical expertise	Minimal training. No special expertise needed. User friendly system (manual provides step by step procedures).
Other: Drive software: Window application or Labview. Optical connector (recommended): FC/PC, FC/APC.	

6. Availability

Upon agreement.

7. On-Going or Completed Bridge Related Projects and References

Load carrying capacity tests on several bridges by Korea Infrastructure Safety & Technology Corporation (KISTEC).
Safety monitoring systems of bridges based on IT technology by Smart Infra-Structure Technology Center (SISTEC).
Many field tests and monitoring projects have been completd and are on-going actively.

References:

- Kang, H.K., Kang, D.H., Hong, C.S., and Kim, C.G. "Simultaneous Monitoring of Strain and Temperature During and After Cure of Unsymmetric Composite Laminate Using Fiber Optic Sensors," Smart Materials and Structures, Institute of Physics Publishing Ltd, pp. 29-35, 2003.
- Kang, H.K., Kang, D.H., Bang, H.J., Hong, C.S., and Kim, C.G. "Cure Monitoring of Composite Laminates using Fiber Optic Sensors," Smart Material and Structuers, Institute of Physics Publishing Ltd, pp. 279-287, 2002.
- Kang, H.K., Park, J.S., Kang, D.H., Kim, C.U., Hong, C.S., and Kim, C.G. "Strain Monitoring of a Filament Wound Composite Tank using Fiber Bragg Grating Sensors," Smart Materials and Structures, Institute of Physics Publishing Ltd, pp. 848-853, 2002.
- Yun, S.H., Richardson, D.J., Kim, B.Y. "Interrogation of Fiber Grating Sensor Arrays with a Wavelength-Swept Fiber Laser," Optics Society of America, Vol. 23, No. 11, pp. 843-845, 1998.

8. Notes

- Founded in 1995, FIBERPRO (operating under ISO9001 system) is a developer and manufacturer of fiber optics solutions for telecommunications, and fiber optic sensor interrogation systems; the company provides standard products and also adapts most products to meet the customer's requirement.
- FIBERPRO USA (for US contact): 3003 N. 1st Street, Suite 134, San Jose, CA 95134 (Tel : 408-519-5735 Fax : 408-519-5736).
- All FIBERPRO's products are managed via Service Files that maintain detailed records and descriptions of products from the date of purchase.
- FIBERPRO interrogator system is capable of multi-purposes; system can be used for strain and temperature profile measurememt for almost every type of bridge; also by using specially designed sensor head, acceleration and incline can be measured.

1. General Information

Description of Technology	Corrosion Monitoring System.	
Manufacturer and Contact information	Force Technology Park Alle 345, 2605 Brondby, Denmark.	www.force.dk Tel: +45 4326-7000 or (713) 975-8300 in US Fax: +45 4326-7011
Features	Sensor type	ERE20: reference electrode suitable for monitoring of corrosion risk and controlling the effect of cathodic protection; for new and existing concrete structures. CorroWatch multiprobe: suitable in new concrete structure.
	Data acquisition, processing, and archiving	CorroLog (8-channel mini data logger): developed for collecting and monitoring low-potential-values; time interval can be specified either in seconds or minutes; user-friendly Window-based software program available for managing interval and delay for readings.
	Communications	Direct connection. Remote monitoring system is being developed.
	'Smart' attributes	
	Other	GalvaPulse equipment: used for measurement of corrosion rate from the concrete surface.

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☐ Timber:	☐ Plank ☐ Nailed laminated ☐ Glue-laminated ☐ Prestressed laminated ☐ Stressed timber ☐ Other:
	☒ Concrete:	☒ Reinforced ☒ Prestressed/post-tensioned ☐ Other:
	☐ Steel:	☐ Grid ☐ Orthotropic ☐ Buckle plate ☐ Corrugated steel flooring ☐ Other:
	☐ FRP:	
Superstructure	*Primary Element*	☒ Multi-beam/girder system: ☒ Girder floor beam/diaphragm system ☒ Tee beam ☒ Box girder ☒ Channel beam ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:
	Secondary Element	☐ Connector and fastener: ☐ Riveted/bolted ☐ Welded ☐ Pin & hanger ☐ Splice ☐ Bracing: ☐ Cross ☐ Lateral ☐ Sway ☐ Diaphragm ☐ Cover plate ☐ Stiffener ☐ Other:
	Bearing	☐ Fixed ☐ Expansion: ☐ Sliding plate ☐ Roller ☐ Rocker ☐ Pin and link ☐ Elastomeric ☐ Pot ☐ Restraining ☐ Other:
	Other:	
Substructure	☒ Abutment:	☒ Footing ☒ Bridge seat ☒ Piles ☒ Wall (stem/back/wing) ☐ Other:
	☒ Pier/bent/extended pile:	☒ Pier cap ☒ Shaft ☒ Column/stem ☐ Submerged pile/pile cap/footing ☐ Other:
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)*	1. Cable-supported bridge ☒ Tower ☐ Main/secondary cable ☐ Cable anchorage ☐ Anchor rod ☐ Damping system ☐ Strand shoes ☐ Cable bands ☐ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:
	Other:	

Monitoring Interest

☐ Crack/fracture ☐ Expansion/contraction ☐ Rotation/torsion ☐ Wear/spalling/scaling/delamination
☐ Section loss ☐ Settlement ☐ Misalignment ☐ Connection failure or deficiencies
☐ Deformation ☐ Wire breakage ☐ Mechanical/electrical malfunction ☐ Impact damage
☐ Debonding ☐ Erosion/scour ☐ Looseness and pounding ☐ Excessive joint closing/opening
☒ Corrosion ☐ Environmental ☐ Other:

Measurement Metric

☐ Strain ☐ Deflection/displacement ☐ Acceleration/vibration ☒ Moisture/humidity level
☒ Temperature ☐ Magnetic field/flux ☒ Electrical voltage/current ☐ Chemical composition
☐ Radar waves ☐ Acoustic waves ☐ Magnetic waves ☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☐ Wind speed/direction ☐ Other:

3. Cost		
Hardware	Sensor	ERE20: $119~$151 per unit. (€1.00-$1.21) CorroWatch: $532~$653 per unit.
	Data acquisition system	CorroLog (8-channel): $575 per unit. Newer version available upon request.
	Communication system	
	Data archiving system	
	Other	Price depends on volumn of order.
Software	$8,470 (price including software and licensing with 1-day of training).	
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	No official life expectancy.
Power	CorroLog: 3.6V AA size Lithium battery (approximate battery life of 1.25 years).
Environmental conditions	-40°C to 75°C.
Data storage/transfer/ processing	
Other:	

5. Implementation Needs	
Power source	Battery.
Accessibility	Direct access needed for sensor installation and data acquisition (remote monitoring system is under development).
Technical expertise	Basic electronics skills. Minimal training for system.
Other:	

6. Availability

Normally 2 to 3 weeks (upon agreement for lager quantity).

7. On-Going or Completed Bridge Related Projects and References

Skovdiget Bridge, Copenhagen.

References:

- Ramboll Denmark. "Integrated Monitoring Systems for Durability Assessment of Concrete Structure" Smart Structures Project Report, Contract No. BRPR-CT98-0751, September 2002.
- Klinghoffer, O., Goltermann, P., and Bassler, R. "Smart Structures: Embeddable Sensors for Use in the Integrated Monitoring Systems of Concrete Structures," 1st International Conference on Bridge Maintenance, Safety and Mangement, IABMAS 2002, Barcelona, Spain, July 14-17, 2002.

8. Notes

- For about 60 years, FORCE Technology has served as a technological partner in development, consultancy, and service for industry in Denmark and abroad; in recent years, FORCE has completed projects in about 60 countries all over the world.
- The company offers various services including concrete inspection, wind engineering analysis, sensor and measuring systems, other types of inspection and testing.
- Other services for evaluating corrosion activity in RC structures include: electro-chemical methods for assessment of the corrosion condition of reinforcing steel including Half-Cell potential measurements and Galvanostatic measurement; permanent monitoring of reinforcement; corrosion by means of embedded sensors; evaluation of condition and potential durability of concrete structures and preparation of suitable strategies for maintenance and repair; laboratory analysis of concrete pore water, measurement of chloride distribution and threshold chloride concentration for initiation of corrosion.

1. General Information

Description of Technology	Fiber optic sensing technology.		
Manufacturer and Contact information	Fiber Optic System Technology, Inc. 4580 Dufferin Street, Toronto, Ontario M3H 5Y2, Canada	www.fox-tek.com Tel: (416) 665-2288 Fax: (416) 665-0494	
Features	Sensor type	FOX-TEK FT fiber optic sensors: depending on the application involved, the sensors are available as bare fiber or embedded in fiber reinforced tape.	
	Data acquisition, processing, and archiving	FTI-3000 sensor scanner: sequentially scan up to eight FT sensors to provide displacement measurements; it can be operated in a local or stand-alone mode using the front panel LCD screen to read the results, or a connection can be made to a PC through the RS232 port to automatically collect and store the data; the instrument is equipped with 8 input channels in a 19" rackmount configuration.	
	Communications	Direct wire connection. Internet. Modem.	
	'Smart' attributes		
	Other	When coupled with FOX-Ware (an integrated server-client and web-interface software package), the FTI-3300 can be remotely controlled and operated over any type of network connection.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☒ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☐ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☒ Main/secondary cable ☒ Cable anchorage ☒ Anchor rod ☒ Damping system ☒ Strand shoes ☒ Cable bands ☒ Cable enclosures ☐ Other: 2. Movable bridge ☒ Electric brakes ☒ Motors and power ☒ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☒ Crack/fracture ☐ Expansion/contraction ☐ Rotation/torsion ☐ Wear/spalling/scaling/delamination
☐ Section loss ☒ Settlement ☐ Misalignment ☐ Connection failure or deficiencies
☒ Deformation ☐ Wire breakage ☐ Mechanical/electrical malfunction ☒ Impact damage
☐ Debonding ☐ Erosion/scour ☐ Looseness and pounding ☐ Excessive joint closing/opening
☐ Corrosion ☐ Environmental ☐ Other:

Measurement Metric

☒ Strain ☒ Deflection/displacement ☐ Acceleration/vibration ☐ Moisture/humidity level
☐ Temperature ☐ Magnetic field/flux ☐ Electrical voltage/current ☐ Chemical composition
☐ Radar waves ☐ Acoustic waves ☐ Magnetic waves ☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☐ Wind speed/direction ☐ Other:

3. Cost		
Hardware	Sensor	$400~$1000 per unit. Price depends on volume of order.
	Data acquisition system	Priced based on specification.
	Communication system	
	Data archiving system	
	Other	
Software	Included with the system.	
Labor	Installation	
	Use	
Other: Fox-Tek does not want to release their product price.		

4. Limitations	
Life expectancy	10 to 20 years.
Power	110/220V AC.
Environmental conditions	4°C to 38°C (without air-conditioning).
Data storage/transfer/ processing	Computer interface: RS232 serial.
Other: Measurement range: ±20 mm or ±4,000 microstrain.	

5. Implementation Needs	
Power source	AC.
Accessibility	Direct access needed for sensor installation and data acquisition (optional remote monitoring and control).
Technical expertise	Engineering background. Moderate training.
Other: System requirements: Pentium II-300 or higher (Pentium III-700 recommended); 64MB Ram (128MB recommended); 50MB free disk space (plus additional space as required for data storage); Windows 2000; 1024x768 minimum monitor resolution.	

6. Availability

2 to 5 weeks.

7. On-Going or Completed Bridge Related Projects and References

Leslie Street Bridge, Canada.
Duncan Bridge, Canada.

8. Notes

- The company is currently developing a new high-powered laser light source and optical switches which integrate or multiplex signals from up to 16 different optical sensor cables.
- With the FTI-3300, small changes in the properties of the structure can be continuously monitored using FT sensors.
- For optimum accuracy, the FTI-3300 should be located in a office environment; with the use of a suitable enclosure, the instrument can function in other conditions.

1. General Information

Description of Technology	Signal conditioning, processing and pattern recognition technologies for data acquisition, data conversion and data translation.	
Manufacturer and Contact information	Frequency Devices, Inc. 25 Locust Street, Haverhill, Massachusetts 01830	www.freqdev.com Tel: (978) 374-0761 or (800) 252-7074 Fax: (978) 521-1839
Features	Sensor type	
	Data acquisition, processing, and archiving	Distribution data logger system. Model 5016 signal conditioning system (simultaneous access over 64 channels with each channel providing differential input, buffered output, with fixed gain of up to +60 dB). CPCI32FF: a single width B-sized (6U) form factor Compact PCI filter/gain board, Simultaneous access to 32 channels with amplification and filtering.
	Communications	From wired to wireless communication (upon request).
	'Smart' attributes	
	Other	90IP/90IPB instrumentation flatform: four slot chassis with controller. Up to 32 of multiple-channel instruments may be chained and addressed from a PC interface to meet the needs of high channel count applications.

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☒ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☒ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☒ Main/secondary cable ☒ Cable anchorage ☒ Anchor rod ☒ Damping system ☒ Strand shoes ☒ Cable bands ☒ Cable enclosures ☐ Other: 2. Movable bridge ☒ Electric brakes ☒ Motors and power ☒ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☐ Crack/fracture	☐ Expansion/contraction	☐ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☐ Section loss	☐ Settlement	☐ Misalignment	☐ Connection failure or deficiencies
☐ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☐ Impact damage
☐ Debonding	☐ Erosion/scour	☐ Looseness and pounding	☐ Excessive joint closing/opening
☐ Corrosion	☐ Environmental	☐ Other:	

Measurement Metric

☒ Strain	☒ Deflection/displacement	☒ Acceleration/vibration	☐ Moisture/humidity level
☒ Temperature	☐ Magnetic field/flux	☒ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☐ Other:	

3. Cost		
Hardware	Sensor	
	Data acquisition system	Model 5016: priced based on specification such as power supply, filter/amplifier card, open frame chassis, etc. CPCI32FF: $3,770 each. 90IP Chassis: $1,100 each. 90IPB (external battery operated): $1,900 each. Program Amplifier: $1,700 each.
	Communication system	
	Data archiving system	
	Other	Rack mount shelf for 90IP/90IPB: $300. Fixed frequency 4-pole filter: $80-90 each.
Software		
Labor	Installation	
	Use	
Other: Complete data acquisition system is priced based on user's requirement.		

4. Limitations	
Life expectancy	No official life expectancy.
Power	Model 5016: 110/240V AC. 90IP: 115/230V AC. 90IPB: 12V DC.
Environmental conditions	0°C to 50°C for Model 5016. 0ºC to 40ºC for 90IP and 90IPB.
Data storage/transfer/ processing	
Other:	

5. Implementation Needs	
Power source	AD/DC.
Accessibility	Direct access or remote data acquisition and monitoring.
Technical expertise	Basic electronic skills. Minimal training.
Other:	

6. Availability

2 to 4 weeks.

7. On-Going or Completed Bridge Related Projects and References

Confederation Bridge, Canada.

8. Notes

- Since 1968, Frequency Devices has provided analog, digital and integrated analog/digital-signal-processing (DSP) solutions for various applications.
- The company offers solutions and custom designs for application specific signal conditioning, processing or manipulation requirements.
- Their products include various complex hardware and software, analog and digital fixed frequency and programmable low-pass, high-pass, band-pass and band-reject (notch) electronic filters along with differential input amplifiers and oscillators.
- Also available is single and multi-channel signal processing platforms and instruments that perform FFT, signal analysis and signal correlation.
- Their system architectures include VME, VXI, compactPCI and PCI form factors as well as IEEE-488, RS-232, Ethernet and USB I/O's with MatLab, Labview and LabWindowsCVI compatible GUI interfaces.

1. General Information

Description of Technology	Movement monitoring system (MMS) and Remote monitoring system (RMS) using GPS and laser technologies.		
Manufacturer and Contact information	GEODEV SA Stabile Gerre, P.O. Box 341, 6928 Manno, Switzerland	www.geodev.ch Tel: +41 91 610 1920 Fax: +41 91 610 1921	
Features	Sensor type	Laser distance meter.	
	Data acquisition, processing, and archiving	RMS system integrates measurement techniques such as satellite geodesy with low power semiconductors, wireless communication, a database system and the Internet. A measurment station can manage multiple sensors (GPS receivers or laser distance meter).	
	Communications	Various communication options: cellular modem, radio modem, satellite communication or by a direct cable connection (RS-485, fiber optics, etc.).	
	'Smart' attributes	Real time, continuous monitoring system with alarm triggering function for over-limit event.	
	Other	MMS is an automonous and automatic GPS-based monitoring system consisting of a number of small mobile measuring stations installed on the object to be monitored, plus one or more mobile reference stations installed at fixed, possibly surveyed locations around the object; used in 3D deformation or displacement monitoring.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☐ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☐ Riveted/bolted ☒ Cross	☐ Welded ☒ Lateral	☐ Pin & hanger ☒ Sway	☐ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☐ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☒ Main/secondary cable ☒ Cable anchorage ☒ Anchor rod ☐ Damping system ☒ Strand shoes ☒ Cable bands ☒ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☐ Crack/fracture ☒ Expansion/contraction ☒ Rotation/torsion ☐ Wear/spalling/scaling/delamination
☐ Section loss ☒ Settlement ☒ Misalignment ☐ Connection failure or deficiencies
☒ Deformation ☐ Wire breakage ☐ Mechanical/electrical malfunction ☒ Impact damage
☐ Debonding ☐ Erosion/scour ☐ Looseness and pounding ☒ Excessive joint closing/opening
☐ Corrosion ☐ Environmental ☐ Other:

Measurement Metric

☐ Strain ☒ Deflection/displacement ☐ Acceleration/vibration ☐ Moisture/humidity level
☐ Temperature ☐ Magnetic field/flux ☐ Electrical voltage/current ☐ Chemical composition
☐ Radar waves ☐ Acoustic waves ☐ Magnetic waves ☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☐ Wind speed/direction ☐ Other:

3. Cost		
Hardware	Sensor	Laser distance meter: $2,768 (with protection box; short distance, up to ca 20m), $4,042 (with protection box and precise targeting screw; long distances, up to ca 600m). Reflector: $47. Viewfinder: $278. GPS antenna (with 5m cable): $551. Additional cable for GPS antenna: $252 (15m), $314 (25m), $376 (35m).
	Data acquisition system	RMS-GPS measurement station with GPS antenna): $7,985. RMS single laser measurement station: $6,145. RMS-GPS ccontrol center (including control unit with rack, and RMS and GPS softwares): $16,811.
	Communication system	Radio modem: $1,473 (free frequencies, <1km), $2,647 (380-470MHz, max distance ca 20km with LOS). GSM modem (including GSM antenna): $1,073. External GSM antenna: $313. RS-485 communication module: $326. RS-232 communication module: $99.
	Data archiving system	Data backup for control unit: $2,037.
	Other	Solar power supply kit: $2,019. DC direct power supply: $322. Backup battery for DC direct power supply: $95.
Software	RMS laser control center software (including RMSs control center base software and laser plugin): $1,331. RMS control center multi network extension: $1,774. Real-time internet data publication module: $3,815.	
Labor	Installation	
	Use	
Other: Isolated box for extreme conditions weather: $1,263. Keyboard and touch pad for control unit rack mounted: $745. LCD 15" display: $1,241. Solar module mounting kit: $698 (pole mounting), $623 (wall mounting). GPS antenna mounting pole: $295 (horizontal), $333 (vertical). RMS box mounting: $16 (wall mounting), $123 (pole mounting).		

4. Limitations	
Life expectancy	No official life expectancy.
Power	110/220V AC or 6 to 30V DC.
Environmental conditions	-30 to 70°C with 5 to 95% relative huminity.
Data storage/transfer/ processing	SDB database.
Other: Accuracy single measurement: 1.5mm. Distance: 0.3m to 1km. Laser: visible, 635 nm.	

5. Implementation Needs	
Power source	AC/DC adapter or solar panel and a battery for situation where no connection to the power grid is available.
Accessibility	Direct access for sensor installation. Remote data acquisition and processing.
Technical expertise	Training on the use of equipment and software. On-site technical support is available. GEODEV also offers consulting services for structural and environmental monitoring, Geographic Information Systems and data acquisition systems, as well as services related to data management, analysis and visualisation over the Internet.
Other: For distance up to 150m, a target plate may be required. For long distance, a prism is necessary. When the distance exceeds 20-30m, the laser must be mounted on a special support for an accurate targeting.	

6. Availability

Approximately 3 months.

7. On-Going or Completed Bridge Related Projects and References

Some bridge related application notes can be found on websites of GEODEV and SMARTEC.

References;

- Frapolli, M., and Manetti, L. "Integrating GPS and Traditional Measuring Instruments for Large Structure Monitoring," Structural Health Monitoring ISIS 2002 Workshop, Winnipeg, Manitoba, Canada, 2002.
- Manetti, L., and Knecht, A. "GPS-based System for autonomous and permanent monitoring of large structures," First International Conference on Bridge Maintenance, Safety and Management, Barcelona, Spain, 2002.
- Knecht, A., and Manetti, L. "Using GPS in structural health monitoring," Proceedings of the SPIE's 8th Annual International Symposium on Smart Structures and Materials, Newport Beach, CA, 2001.
- Other references available on company website.

8. Notes

- GEODEV is specialized in developing, manufacturing and selling equipment and services for environmental and structural monitoring, remote data acquisition and dissemination utilizing remote sensing systems, space geodesy techniques (GPS), wireless data transmission, Internet and Geographic Information Systems (GIS).
- GEODEV also develops and manufactures customizable data acquisition instruments and monitoring systems to offer to its customer's needs.

1. General Information

Description of Technology	Geotechnical instruments and data acquisition system for geotechnical and structural monitoring applications.	
Manufacturer and Contact information	GeoIndicator Ltd. 4th floor-22 Buckingham Gate, SW1E 6LB London, UK	www.geoindicator.cocm Tel: +44 77 6605 5485 Fax: +44 20 7486 1830
Features	Sensor type	Vibrating wire (VW) strain gage, accelerometers, extensometer, piezometer, joint meter, thermometer, tilt sensor and others.
	Data acquisition, processing, and archiving	ADK-10 (milti-function data logger): it is a microcomputer, clock, multimeter, calibrator, scanner, frequency counter and controller; allows simultaneous communication and measurement functions; basic module has 12 analog channels allowing six differential channels to be scanned; scan intervals are programmable.
	Communications	Local and remote comunication by RS232 COM port, MD-9 direct connection, GSM or phone modem.
	'Smart' attributes	Automatic alarm notification of any sensor parameter when a preset threshold value is exceeded; control actions can be activated on alarm conditions.
	Other	Multiplexers provide additional inputs for up to 192 analog or differential channels. Transient and EMI protection are provided using spark gaps or transzorbs at all wiring connections.

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☒ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☐ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☐ Strand shoes 2. Movable bridge ☐ Electric brakes	☐ Main/secondary cable ☐ Cable bands ☐ Motors and power	☐ Cable anchorage ☐ Cable enclosures ☐ Operating machinery and equipment	☐ Anchor rod ☐ Other:	☐ Damping system ☐ Other:	
	Other:					

Monitoring Interest

☒ Crack/fracture	☒ Expansion/contraction	☒ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☐ Section loss	☒ Settlement	☒ Misalignment	☐ Connection failure or deficiencies
☒ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☒ Impact damage
☐ Debonding	☐ Erosion/scour	☒ Looseness and pounding	☒ Excessive joint closing/opening
☐ Corrosion	☒ Environmental	☒ Other: Seismic activity.	

Measurement Metric

☒ Strain	☒ Deflection/displacement	☒ Acceleration/vibration	☐ Moisture/humidity level
☒ Temperature	☐ Magnetic field/flux	☐ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☐ Other:	

3. Cost		
Hardware	Sensor	VW strain gauges: $133 per unit (€1.00 = $1.21). VW piezometers: $424 per unit. Jointmeters: $436 per unit. Thermometers: $85 per unit. Tilt sensors: $690 per unit.
	Data acquisition system	ADK-10 cabinet (128 KRAM): $6,050. VW excitation module: $182 each. Three-Multiplexer boards (16/32 channels): $3,449 ($1,150 each). Three-Multiplexer surge arrestor kits: $546 ($182 each).
	Communication system	
	Data archiving system	
	Other	
Software	Mulilogger ADK-10 software (Window version): $1,573.	
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	No official life expectancy.
Power	9.6 to 16V DC. AC voltage must be centered around CR10X ground. Any 12V battey can be connected aas a primary power source.
Environmental conditions	ADK-10: -25 to 50°C.
Data storage/transfer/ processing	Depends on specification.
Other:	

5. Implementation Needs	
Power source	AC/DC.
Accessibility	Direct access needed for system installation and data collection. Remote central data acquisition and processing system is optional upon request.
Technical expertise	Engineering background. Minimal training for the use of software.
Other: Recommended system resources for multilogger software: Pentium II or higher processer; 32 MB memory; 20MB hard disk.	

6. Availability

3 to 4 weeks.
24 months warranty.

7. On-Going or Completed Bridge Related Projects and References

Milano-Napoli high speed Motorway, Italy.
Adana Buyuksehir Belediyesi Light Railway, Turkey.

Reference:

• Thomson, P., Marulanda, J., Galindez, N., Caicedo, J.M., Dyke, S.J., and Orozco, A. "Implementation of a Modal Identification Methodology on the Pereira-Dos Quebradas Cable-Stayed Bridge," 16th ASCE Engineering Mechanics Conference, University of Washington, Seattle, Washington, July 16-18, 2003.

8. Notes

- GeoIndicator is one of the international sales coordinators of SISGEO (www.sisgeo.it); SISGEO was founded in 1993 and designs and manufactures measuring instruments and related data acquisition systems for geotechnical and structural applications.
- Up to 256 ADK-10 data loggers can be interconnected using a single coaxial cable and the MD interface, to allow all data loggers to be accessed by a central computer.
- ADK-10 is built around the Campbell Scientific CR10 measurement and control module.

1. General Information

Description of Technology	Structural monitoring system with vibrating wire sensor technologies.	
Manufacturer and Contact information	Geokon, Inc. 48 Spencer St. Lebanon, NH 03766	www.geokon.com Tel: (603) 448-1562 Fax: (603) 448-3216
Features	Sensor type	Strain sensors, jointmeter, crackmeter, tiltmeter, etc.
	Data acquisition, processing, and archiving	Single or multi-channel data logger: housed in a rugged, weather-resistant Nema4x aluminum enclosure; easy to use for all types of vibrating wire sensors; channels can be expaned with multiplexers. Software allows easy programming of scan intervals, selection of sensor types, setting of alarms, etc.
	Communications	Data is retrieved by telephone modem, via Internet/Ethernet, solid state storage module, radios, or satellite transmission.
	'Smart' attributes	Real-time, continuous monitoring with alarm triggering capability.
	Other	Windows based MultiLogger software allows easy programming of scan intervals, selection of sensor types, setting alarms, etc.

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☒ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☒ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☐ Strand shoes 2. Movable bridge ☐ Electric brakes	☐ Main/secondary cable ☐ Cable bands ☐ Motors and power	☐ Cable anchorage ☐ Cable enclosures ☐ Operating machinery and equipment	☐ Anchor rod ☐ Other:	☐ Damping system ☐ Other:	
	Other:					

Monitoring Interest

☒ Crack/fracture ☒ Expansion/contraction ☒ Rotation/torsion ☐ Wear/spalling/scaling/delamination
☐ Section loss ☒ Settlement ☒ Misalignment ☐ Connection failure or deficiencies
☒ Deformation ☐ Wire breakage ☐ Mechanical/electrical malfunction ☒ Impact damage
☐ Debonding ☐ Erosion/scour ☐ Looseness and pounding ☐ Excessive joint closing/opening
☐ Corrosion ☒ Environmental ☐ Other:

Measurement Metric

☒ Strain ☒ Deflection/displacement ☒ Acceleration/vibration ☐ Moisture/humidity level
☒ Temperature ☐ Magnetic field/flux ☒ Electrical voltage/current ☐ Chemical composition
☐ Radar waves ☐ Acoustic waves ☐ Magnetic waves ☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☐ Wind speed/direction ☐ Other:

3. Cost		
Hardware	Sensor	Strain gage sensor: Model 3900 ($350.00 each + $1.03/ft. cable); Model 4000 ($125.00 each + $0.51/ft. cable); Model 4200 ($115.00 each + $0.51/ft. cable); Model 4911 ($290.00 each + $0.62/ft. cable). Jointmeter: Model 4400 $485.00 each + $0.62/ft cable. Tiltmeter: Model 6700-1-H Horizontal Tilt Sensor assembly ($340.00 each + $1.03/ft. cable) or 6700-1-V Vertical Tilt Sensor assembly ($390.00 each + $1.03/ft. cable); 6700-2-1H 1m Horizontal Beam ($120.00 each); 6700-2-1V 1m Vertical Beam ($150.00 each); 6700-2-2H 2m Horizontal Beam ($130.00 each); 6700-2-2V 2m Vertical Beam ($160.00 each).
	Data acquisition system	8001 LC-1 ($710.00 each + $35.00 per 10-pin connector, attached to VW gage cable; 8001-2 Included at no charge with LC-1). 8020 (Base price = $5,000.00); 8020-2 ($895.00). 8032 (Model 8032-26-1 16x4-channel multiplexer = $950.00 each, Model 8032-32-1 32x2-ch = $1,000 each).
	Communication system	
	Data archiving system	
	Other	For surge protection, add $200.00 to 8032-16-1 price, $400.00 to 8032-32-1 price.
Software	8020DB (There are 3 parts to the DB package): MultiLogger software price is $895.00, plus $495.00 for MultiLogger DB Interbase Server Software, with an additional $895.00/per datalogger for MultiLogger DB software/licensing.	
Labor	Installation	
	Use	
Other: 6700-3 Installation tools: $35.00. RB-200 Readout Box: $955.00.		

4. Limitations	
Life expectancy	No official life expectancy.
Power	8020 Micro-10 data logger (12V battery, 7.0 Amp Ahr Gel Cell), Spead sectrum wireless field station (12V DC).
Environmental conditions	8020 Micro-10 data logger :-23°C to 50°C; Spread spectrum wireless field station: 0 to 70°C; 8032 Mltiplexer: -20°C to 80°C; (all without air conditioning).
Data storage/transfer/ processing	Depends on products.
Other:	

5. Implementation Needs	
Power source	Battery, AC/DC, solar panal.
Accessibility	Direct access needed for sensor installation. Remote data acquisition and control.
Technical expertise	Minimal training on how to use the system.
Other: System requirements: 486 running at 25 MHz (minimum) Pentium/Pentium Pro/Pentium II or higher running at 166 MHz or better.	

6. Availability

1 to 3 weeks depending on products (may take longer for custom design products).

7. On-Going or Completed Bridge Related Projects and References

New Kao Ping Bridge, Taiwan.
Marbella Relief Road Viaduct, Spain.
Many other projects in many countries.
Some cases studies are available on company website.

8. Notes

- Geokon has been awarded ISO 9001:2000 registration from both ANSI/RAB, USA and UKAS of Great Britain.
- The company provides complete installation training services; engineers and technicians alvailable to assist at project sites worldwide.
- Certain instruments are available for rental.
- The company also offers a comprehensive design service and custom instrumentation for special applications.

1. General Information

Description of Technology	Field monitoring data acquisition and control system for physical measurements.	
Manufacturer and Contact information	Geomation, Inc. 14828 W 6th Ave, Ste 1-B, Golden, Colorado 80401	www.geomation.com Tel: (720) 746-0100 Fax: (720) 746-1100
Features	Sensor type	
	Data acquisition, processing, and archiving	OutDAQ 3300 Remote Terminal Unit (RTU) with SCADA host software: capable of a local display, current measurements, configuring software options, and performing diagnostic operations. System 2380 Measurement & Control Units (MCU) with GEONET software: provides a comprehensive system for field data acquisition and control.
	Communications	MCUs can be linked by radio, wireline, microwave and public communication networks.
	'Smart' attributes	Real time, continuous monitoring with autonomous alarm triggering option upon request.
	Other	Wireline digital link (WDL), Fiber-optic link (FOL), and Radio modem link (RML) converts RS-232 signals to RS-485 multi-drop interface, to fiber-optic compatible signal, and to RF data transceiver, respectively.

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☒ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☒ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☒ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☒ Main/secondary cable ☒ Cable anchorage ☒ Anchor rod ☒ Damping system ☒ Strand shoes ☒ Cable bands ☒ Cable enclosures ☐ Other: 2. Movable bridge ☒ Electric brakes ☒ Motors and power ☒ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☐ Crack/fracture ☐ Expansion/contraction ☐ Rotation/torsion ☐ Wear/spalling/scaling/delamination
☐ Section loss ☒ Settlement ☐ Misalignment ☐ Connection failure or deficiencies
☐ Deformation ☐ Wire breakage ☐ Mechanical/electrical malfunction ☐ Impact damage
☐ Debonding ☐ Erosion/scour ☐ Looseness and pounding ☐ Excessive joint closing/opening
☐ Corrosion ☐ Environmental ☐ Other:

Measurement Metric

☐ Strain ☐ Deflection/displacement ☐ Acceleration/vibration ☐ Moisture/humidity level
☐ Temperature ☐ Magnetic field/flux ☐ Electrical voltage/current ☐ Chemical composition
☐ Radar waves ☐ Acoustic waves ☐ Magnetic waves ☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☐ Wind speed/direction ☐ Other:

3. Cost		
Hardware	Sensor	
	Data acquisition system	MCU 2380 (2 I/O module capacity: $2,500, 8 I/O module capacity: $3,900). OutPAK RTU, solar powered, 2.4GHz host link: $4,650~$5,622 (with radio I/O Xbus extension).
	Communication system	WDL: $400. FOL: $850. RML: $750-1350. Telephone Network Modem: $375. Radio link kit (external to MCU): $650. Omnidirectiional antenna: $650. Satellite Modem-to-Radio repeater: $5,875 (900MHz)~$5,950 (2.4GHz). Satellite communication modem kit: $1,900.
	Data archiving system	FlashDisk mass storage PC card (64MB, 1,200,000 measureents): $400.
	Other	Multiplexer: $450 (analog sinal) - 500 (resistance ratio). Multi-stage transient arrestor: $75 (2 wires)~$450 (20 wires). Serial line converter RS-232/RS 485: $125. Serial line isolator/driver pair with cables: $650.
Software	GEONET suite software (on CD): $0. Published documentation set (GEONET suite): $125. GEONET developer's kit software and printed documentation: $995. RTU configurator (included with RTU). GENESIS/DataWorX OPC Log, Trend, Alarm, Graphics & Report software: $ 3,225 (75 Tag), $4,275 (150 Tag), $5,825 (300 Tag), and $9,075 (1,500 Tag).	
Labor	Installation	Applications engineering support, installation supervision, customer site training: $120/hr.
	Use	Maintenance service: upon request.
Other: Excitation power supplies: $150. External rechargeable battery kit: $50. Cahrer input transformer: $50. External battery charger: $175. Isolated 24V power supply: $85-150. Solar panel with mounting kit: $275 (10-Watt)~$500 (20-Watt). MicroSolar power pack: $500. Back panel mount enclosure: $750~$900. Cross-connect termination enclosure: $950~$1,350. RTU field enclosure: $550~$900. Field encloure: $675 (for Cable-extended I/O)~$905 (for Radio-extendd I/O) Cable: $1.90/m (RS-485 wireline, PVC jacket)~$2.60/m (I/O Xbus, CPE jacket).		

4. Limitations	
Life expectancy	No official life expectancy.
Power	MCU: Absolute Min./Max. Supply Voltage of 10.5-16V DC; Min./Max. Charge Input of 17-35V DC. RTU: Input power of 7-30V DC.
Environmental conditions	Operating Temperature: -40 to 70°C. Relative Humidity: 8 to 95% non-condensing.
Data storage/transfer/ processing	Signaling interface: RS232, Anync, 300 bps to 115.2 kbps. Modbus RTU and Modbus ASCII.
Other: System requirements: Windows 95/98/NT or XP; Intel 80L186EC processor.	

5. Implementation Needs	
Power source	Battery, AC/DC, solar panel.
Accessibility	Remote monitoring data acquisition system.
Technical expertise	Basic or advanced factory training (3-day course): $1,200.
Other:	

6. Availability

2 to 8 weeks.

7. On-Going or Completed Bridge Related Projects and References

Bridge related projects not found.

References:

- Bahr, J.C. "Development of Graphical User Interfaces for Analysis of Field Data," Field Measurements in Geomechanics Symposium, Singapore, 1999.
- Klebba, J.M. "Automated Data Acquisition Systems For Dam Performance Monitoring," International Conference on Dam Safety and Monitoring in Hubei, China, 1999.

8. Notes

- Geomation was founded in 1982 and has developed technologies and devices for obtaining physical measurements from the field.
- System 2300 was designed specifically to overcome the barriers inherent in collecting data automatically from instrument clusters deployed within and around dam structures.
- OutDAQ uses industry standard communication protocols.
- Geomation's system architecture is optimized for very low power consumption with battery operation and wireless communication options; the system has relatively low bandwidth, resulting from the distributed multi-node architecture, the remote communication options, and the low power design. These aspects may limit its application for recording dynamic data.
- Geomation offers a fee-based, comprehensive on-site services including: applications engineering support, installation supervision services, programming and start-up services, other services related to customer requested troubleshooting and possible field repair of equipment.

1. General Information

Description of Technology	Automated tiltmeter monitoring of bridge and bridge components.	
Manufacturer and Contact information	Applied Geomechanics Inc. 1336 Brommer Street, Santa Cruz, CA 95062	www.geomechanics.com Tel: (831) 462-2801 Fax: (831) 462-4418
Features	Sensor type	Electrolytic tiltmeters, clinometer, inclinometer.
	Data acquisition, processing, and archiving	Data acquisition system or digital tiltmeter can record relative movements of bridge components and can compare such movements to predetermined thresholds and/or provide associcated displacement data. Several data acquisition methods are available and can be setup for the specific requirements of users.
	Communications	Direct wire connection (PC direct connection). Other options include telephone lines, cellular, Internet/Ethernet, radio, etc.
	'Smart' attributes	Continuous recording of relative movement of bridge and associated displacement data; automatic alarming system through telephone notification, warning lights, etc. when exceeding predetermined thresholds.
	Other	Digital tiltmeters have self logging capability and can be used to control external devices.

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☒ Nailed laminated ☒ Glue-laminated ☒ Prestressed laminated ☒ Stressed timber ☐ Other:
	☒ Concrete:	☒ Reinforced ☒ Prestressed/post-tensioned ☐ Other:
	☒ Steel:	☒ Grid ☒ Orthotropic ☒ Buckle plate ☒ Corrugated steel flooring ☐ Other:
	☒ FRP:	
Superstructure	*Primary Element*	☒ Multi-beam/girder system: ☒ Girder floor beam/diaphragm system ☒ Tee beam ☒ Box girder ☐ Channel beam ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:
	Secondary Element	☐ Connector and fastener: ☐ Riveted/bolted ☐ Welded ☐ Pin & hanger ☐ Splice ☒ Bracing: ☒ Cross ☒ Lateral ☒ Sway ☒ Diaphragm ☐ Cover plate ☒ Stiffener ☐ Other:
	Bearing	☒ Fixed ☒ Expansion: ☒ Sliding plate ☒ Roller ☒ Rocker ☒ Pin and link ☒ Elastomeric ☒ Pot ☒ Restraining ☐ Other:
	Other:	
Substructure	☒ Abutment:	☒ Footing ☒ Bridge seat ☒ Piles ☒ Wall (stem/back/wing) ☐ Other:
	☒ Pier/bent/extended pile:	☒ Pier cap ☒ Shaft ☒ Column/stem ☐ Submerged pile/pile cap/footing ☐ Other:
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)*	1. Cable-supported bridge ☒ Tower ☐ Main/secondary cable ☐ Cable anchorage ☐ Anchor rod ☒ Damping system ☐ Strand shoes ☐ Cable bands ☐ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:
	Other:	

Monitoring Interest

☐ Crack/fracture	☒ Expansion/contraction	☒ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☐ Section loss	☒ Settlement	☒ Misalignment	☐ Connection failure or deficiencies
☒ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☒ Impact damage
☐ Debonding	☒ Erosion/scour	☒ Looseness and pounding	☐ Excessive joint closing/opening
☐ Corrosion	☐ Environmental	☒ Other: Creep effect.	

Measurement Metric

☐ Strain	☒ Deflection/displacement	☐ Acceleration/vibration	☐ Moisture/humidity level
☐ Temperature	☐ Magnetic field/flux	☐ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☐ Other:	

3. Cost		
Hardware	Sensor	Approximately $800 per unit.
	Data acquisition system	$5,000~$8,000
	Communication system	
	Data archiving system	$1,200.
	Other	
Software	$400.	
Labor	Installation	$1,200~$10,000.
	Use	Approximately <$1,000/year.
Other: Costs are highly variable depending on the type and number of sensors, their relative distances from the data acquisition system and the communication option selected.		

4. Limitations	
Life expectancy	20 years plus.
Power	110/220V AC. 12V DC.
Environmental conditions	-40°C to 85°C.
Data storage/transfer/ processing	Depends on specification.
Other:	

5. Implementation Needs	
Power source	AC/DC.
Accessibility	Required for instrument mounting; cables lead to DAS from each instrument.
Technical expertise	Basic elecronics and computer skills, knowledge of bridge engineering and dynamics; minimal training required for sensor installation and data control and mamagement.
Other:	

6. Availability

Readily available. Need several weeks for a custom system.

7. On-Going or Completed Bridge Related Projects and References

Automated tiltmeter monitoring of Laurel Street Bridge response to compaction grouting, Santa Cruz, CA
Load testing on Parrotts Ferry Bridge, Vallecito, CA

References:
- Schuyler, J.N., and Gularte, F. "Automated Tiltmeter Monitoring of Bridge Response to Compaction Grouting," Applied Geomechanics Inc.
- Some other references and case studies are available on company website.

8. Notes

- Founded in 1982, Applied Geomechanics Inc. provides combined systems includint tiltmeters and other sensors (strain gages, joint meters, load cells, etc.) as required by customer.
- Applied GeoMechanics' system provides the record of all angular movements with respect to gravity, eliminates the need for locating a stable benchmark or other datum; movement or rotations of a structure induced by settlement or loading are directly converted to displacements, moduli, moments, and shears using standard engineering formulae.
- Newly available data acquisition device is 'ADVisor'; a wireless handheld data logging device capable of collecting data from an array of tiltmeters in projects where continuous data logging is not necessary or is too expensive. The ADVisor automatically collects readings at the touch of a stylus and then stores them in an organized database along with instrument locations, ID numbers and project notes.

1. General Information

Description of Technology	Seismic, structural and dynamic monitoring and measuring devices and technologies.		
Manufacturer and Contact information	GeoSIG Ltd. Europastrasse 11, 8152 Glattbrugg, Switzerland	www.geosig.com Tel: +41 1 810 21 50 Fax: +41 1 810 23 50	
Features	Sensor type	Acclerometers. Velocity sensors. Sensors are housed in a rugged, compact cast aluminum case.	
	Data acquisition, processing, and archiving	Central recording system (PC based central recording system): multi-channel recorder containing several recorder module cards; it can be extended to a large number of channels by adding further 12/16/18/24 bit triggered recorder module cards; provides on-line surveillance, common trigger, common sampling and time synchronization; provides near real-time display of the dynamic channels and static data.	
	Communications	Direct wire connection. Communicate with RS-422. Optional GPS, telephone and radio modem interface.	
	'Smart' attributes	On-line surveillence, diagnostics, self-checking and reporting system with automatic alarm triggering (alram relay: 1 global, 5 individuals).	
	Other	Central recording system is expandable up to 120 dynamic and 500 static channels.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☐ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☐ Cover plate ☐ Stiffener ☐ Other:	☐ Riveted/bolted ☒ Cross	☐ Welded ☒ Lateral	☐ Pin & hanger ☒ Sway	☐ Splice	
	Bearing ☐ Fixed ☐ Expansion: ☐ Other:	☐ Sliding plate	☐ Roller	☐ Rocker	☐ Pin and link	☐ Elastomeric ☐ Pot ☐ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☐ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☐ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☐ Main/secondary cable ☐ Cable anchorage ☐ Anchor rod ☐ Damping system ☐ Strand shoes ☐ Cable bands ☐ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☐ Crack/fracture	☐ Expansion/contraction	☐ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☐ Section loss	☐ Settlement	☐ Misalignment	☐ Connection failure or deficiencies
☐ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☒ Impact damage
☐ Debonding	☐ Erosion/scour	☐ Looseness and pounding	☐ Excessive joint closing/opening
☐ Corrosion	☐ Environmental	☒ Other: Seismic activity.	

Measurement Metric

☐ Strain	☐ Deflection/displacement	☒ Acceleration/vibration	☐ Moisture/humidity level
☐ Temperature	☐ Magnetic field/flux	☐ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☐ Other:	

3. Cost		
Hardware	Sensor	Triaxial accelerometer: $1,660 (Model AC-23), $2,800 (Model AC-63) per unit. Triaxial seismometer: $2,465 (Model VE-53) per unit. Triaxial velocity sensor: $1,575 (Model VE-23) per unit.
	Data acquisition system	Strong Motion Recorder: $2,500-$4,325 depending on type of on-board memory cards being included. Central Recorder, SMS seismic monitoring system and SAS seismic alarm system are priced based on number of channel and channel capacity. Alarm Interface card (Model GXR-ALC): $385.
	Communication system	Spread spectrum radio station (Model TEL-SSCS): $6,375 for central station (need one per network), $5,950 for outside station (need one per instrument). Coaxial cable (Model TEL-SSR-CAB1) for spread-spectrum radio: $300; need one per radio station, including the central station. GPS receiver (Model GXR-GPS): $725; need one per independent accelerograph.
	Data archiving system	
	Other	Soar power equipment (Model SOLE): specification and price depends on power requirements and sloar radiation; $2,720 for a typical system with 2.4 AH battery.
Software	GeoDAS software: $85 for GeoDAS-COM Communications software, $510 for GeoDAS-DAP data analysis package.	
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	No official life expectancy.
Power	115/230V AC; 12V DC; One internal battery with 12V DC
Environmental conditions	Sensors: -40 to 70°C. Monitoring system: -20 to 60°C.
Data storage/transfer/ processing	20 to 1,000 Hz sample rate. Large storage available.
Other:	

5. Implementation Needs	
Power source	AC/DC, solar pannel.
Accessibility	Direct access for sensor installation. Monitoring and data acquisition can be performed remotely.
Technical expertise	Engineering background. Training for the system available.
Other: Window 95/98/2000, NT or newer version.	

6. Availability

Approximately 12 weeks.

7. On-Going or Completed Bridge Related Projects and References

Oresund Cable Stayed Bridge, Denmark and Sweden, 2000.
Several case studies and referrences are available on company website.

8. Notes

- GeoSIG was founded in 1979 and has developed and manufactured various types of geophysical instrumentation.
- The system is rugged with industrial packaging standard; galvanic isolation and serge protected.
- GPS synchronized recording system available.
- Real-time display of dynamic channels.
- Large capacity data storage option.
- SAS Seismic Alarm system allows monitoring the sensors continuously; automatically detects seismic events, generates associated alarms and records the event as evidence of the alarm.
- Spread Spectrum Radio Central/Outside Station includes or feasures: receiver and transmitter module; for maximum of 12 outside station channels at 100 samples per second; onmidirectional antenna (9 or 18 dB), excluding mask; lightning protection; battery and battery charger; housing.

1. General Information

Description of Technology	Seismic, structural and dynamic monitoring and measuring technologies.		
Manufacturer and Contact information	Geo Space, LP 7334 N. Gessner, Houston, Texas 77040	www.geospacelp.com Tel: (713) 939-7093 Fax: (713) 937-8012	
Features	Sensor type	Low Frequency Seismometers. GS-1 (1.0 Hz seismometer, vertical or horizontal). SeisMonitor (consisting of three GS-1's in tri-axial configuration in sigle container). HS-1 (2.0 Hz, mini seismometer, vertical or horizontal).	
	Data acquisition, processing, and archiving	GeoWatch: tri-axial GS1 sensor package with self contained (24 bit) data logger. It uses Li/ion rechargeable battery pack and 2GB flash card storage.	
	Communications	Direct wire connection.	
	'Smart' attributes		
	Other	GS-1 detects small displacement motion (0.25 in.) in frequency bandwidth of 1-150 Hz. The seismometer outputs an anlog voltage (velocity) corresponding directly to the case motion. It is passive device that can drive long lengths of sensor wire without amplification.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☐ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☐ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☐ Cover plate ☐ Stiffener ☐ Other:	☐ Riveted/bolted ☒ Cross	☐ Welded ☒ Lateral	☐ Pin & hanger ☒ Sway	☐ Splice	
	Bearing ☐ Fixed ☐ Expansion: ☐ Other:	☐ Sliding plate	☐ Roller	☐ Rocker	☐ Pin and link	☐ Elastomeric ☐ Pot ☐ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☐ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☐ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☐ Strand shoes 2. Movable bridge ☐ Electric brakes	☐ Main/secondary cable ☐ Cable bands ☐ Motors and power	☐ Cable anchorage ☐ Cable enclosures ☐ Operating machinery and equipment	☐ Anchor rod ☐ Other:	☐ Damping system ☐ Other:	
	Other:					

Monitoring Interest

☐ Crack/fracture	☐ Expansion/contraction	☐ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☐ Section loss	☐ Settlement	☐ Misalignment	☐ Connection failure or deficiencies
☒ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☐ Impact damage
☐ Debonding	☐ Erosion/scour	☐ Looseness and pounding	☐ Excessive joint closing/opening
☐ Corrosion	☐ Environmental	☒ Other: Seismic activity.	

Measurement Metric

☐ Strain	☒ Deflection/displacement	☒ Acceleration/vibration	☐ Moisture/humidity level
☐ Temperature	☐ Magnetic field/flux	☐ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☐ Other:	

3. Cost		
Hardware	Sensor	GS-1: $995 per unit. SeisMonitor: $3,390 per unit. HS-1: $295 per unit. MiniSeisMonitor: $1,790 per unit.
	Data acquisition system	GeoWatch: priced by requirements.
	Communication system	
	Data archiving system	
	Other	
Software		
Labor	Installation	
	Use	
Other: Calibration coil: $50 each. Weather resistant cover (for outdoor deployment): $60 each. Mating connector to SeisMonitor with 3 meter pigtail: $100 each.		

4. Limitations	
Life expectancy	No official life expectancy.
Power	
Environmental conditions	-40 to 100°C.
Data storage/transfer/ processing	
Other: GS-1 has natural frequencies from 1.0 to 2.0 Hz., with sensitivities from 3.0 to 15V/in./sec. HS-1 has natural frequencies from 4.5 to 28 Hz., with sensitivities from 460 to 1,150 mV/in./sec.	

5. Implementation Needs	
Power source	Rechargeable battery.
Accessibility	Direct access needed for sensor installation and data acquisition.
Technical expertise	Basic skills of electronics and knowledge of dynamics.
Other:	

6. Availability
Approximately 5 weeks.

7. On-Going or Completed Bridge Related Projects and References
Bridge related project information not available.

8. Notes
• Established as Hall Sears in 1957, Geo Space has developed and manufactured digital grade, small size geophone, seismometers. • HS-1 is an integral component and can be used for the monitoring and analysis of machinery vibration.

1. General Information

Description of Technology	Ground Penetrating Radar (GPR) for bridge deck monitoring: BridgeScan and StructureScan.	
Manufacturer and Contact information	Geophysical Survey Systems, Inc. (GSSI) 13 Klein Dr, PO Box 97, North Salem, New Hampshire 03073	www.geophysical.com Tel: (603) 893-1109 Fax: (603) 889-3984
Features – Sensor type		
Features – Data acquisition, processing, and archiving	BridgeScan: GPR sensing and data acquisition system for bridge deck inspection and analysis; tools for investigation of the condition of aging bridge decks as well as new construction or repair work; system includes a SIR-3000 data acquisition system (digital Subsurface Interface Radar System), survey cart with encoder, 1.5 GHz ground coupled antenna, RADAN software with the Bridge Assessment Module and system accessories.	
Features – Communications		
Features – 'Smart' attributes		
Features – Other	Using the same hardware (SIR-3000 and 1.5 GHz antenna), one can perform "StructureScan" measurements to locate rebar).	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☐ Timber: ☐ Plank ☐ Nailed laminated ☐ Glue-laminated ☐ Prestressed laminated ☐ Stressed timber ☐ Other:	
	☒ Concrete: ☒ Reinforced ☒ Prestressed/post-tensioned ☐ Other:	
	☐ Steel: ☐ Grid ☐ Orthotropic ☐ Buckle plate ☐ Corrugated steel flooring ☐ Other:	
	☐ FRP:	
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Girder floor beam/diaphragm system ☒ Tee beam ☒ Box girder ☒ Channel beam ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	
	Secondary Element ☐ Connector and fastener: ☐ Riveted/bolted ☐ Welded ☐ Pin & hanger ☐ Splice ☐ Bracing: ☐ Cross ☐ Lateral ☐ Sway ☐ Diaphragm ☐ Cover plate ☐ Stiffener ☐ Other:	
	Bearing ☐ Fixed ☐ Expansion: ☐ Sliding plate ☐ Roller ☐ Rocker ☐ Pin and link ☐ Elastomeric ☐ Pot ☐ Restraining ☐ Other:	
	Other:	
Substructure	☒ Abutment: ☒ Footing ☒ Bridge seat ☐ Piles ☒ Wall (stem/back/wing) ☐ Other:	
	☒ Pier/bent/extended pile: ☒ Pier cap ☒ Shaft ☒ Column/stem ☐ Submerged pile/pile cap/footing ☐ Other:	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☐ Main/secondary cable ☐ Cable anchorage ☐ Anchor rod ☐ Damping system ☐ Strand shoes ☐ Cable bands ☐ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:	
	Other:	

Monitoring Interest

☒ Crack/fracture ☒ Expansion/contraction ☐ Rotation/torsion ☒ Wear/spalling/scaling/delamination
☐ Section loss ☐ Settlement ☐ Misalignment ☐ Connection failure or deficiencies
☐ Deformation ☐ Wire breakage ☐ Mechanical/electrical malfunction ☐ Impact damage
☐ Debonding ☐ Erosion/scour ☐ Looseness and pounding ☐ Excessive joint closing/opening
☒ Corrosion ☒ Environmental ☐ Other:

Measurement Metric

☐ Strain ☐ Deflection/displacement ☐ Acceleration/vibration ☐ Moisture/humidity level
☐ Temperature ☐ Magnetic field/flux ☐ Electrical voltage/current ☐ Chemical composition
☐ Radar waves ☐ Acoustic waves ☐ Magnetic waves ☒ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☐ Wind speed/direction ☐ Other:

3. Cost		
Hardware	Sensor	StructureScan: priced based on different needs.
	Data acquisition system	BridgeScan: $24,900 with a 3 day training class included.
	Communication system	
	Data archiving system	
	Other	
Software	Included.	
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	No official life expectancy.
Power	Charging power requirements: 15V DC, 4 amps. Battery: 10.8V DC, internal with 3 to 6 hr life.
Environmental conditions	-10 to 40°C.
Data storage/transfer/ processing	512 Mb Flash memory card. CF memory up to 1 GB. 32-bit Intel SrongArm RISC procesor @ 206 MHz. Scan rate example: 300 scans/sec at 256 samples/scan, 150 scans/sec at 512 samples/scan.
Other: Display: Enhanced 8.4" TFT, 800x600 resolution, 64k color.	

5. Implementation Needs	
Power source	Battery, DC.
Accessibility	
Technical expertise	Minimal training on how to operate the system. Significant expertise needed to interpret test results.
Other:	

6. Availability

45 days.

7. On-Going or Completed Bridge Related Projects and References

Rt-378 Bridge over D&H Railroad and Rt-66 Bridge over Kinderhook Creek, New York.
Central Artery-Tunnel Project ("The Big Dig"), Boston, Massachusetts.
State of New Hampshire: 9 bridge decks.
State of Virginia: 22 multi-lane deck structures on I-95 though Richmond.
State of Wisconsin: over 20 bridge decks.
State of Missouri: over 12 concrete decks.

Reference:

• Romero, F.A., Roberts, G.E., and Roberts, R.L. "Evaluation of GPR Bridge Deck Survey Results Used for Delineation of Removal/Maintenance Quantity Boundaries on Asphalt-Overaid, Reinforced Concrete Deck," Geophysical Survey Systems, Inc.

8. Notes

- BridgeScan can identify rebar location and depth, obtain overlay thickness, determine concrete cover depth, and define area of delamination.
- For StructutreScan, user would need to purchase the Model 615 hand cart and additional software (3D Quickdraw, interactive 3D) to obtain full StructureScan capability; or, one could purchase a StructureScan system and buy extra components to perform bridge scanning; it depends on how the system will be used the most.

1. General Information

Description of Technology	Strain gages, force, torque, pressure transducers, load cells and measurement and monitoring equipment.		
Manufacturer and Contact information	Hottinger Baldwin Messtechnik (HBM), Inc. 19 Bartlett Street, Marlborough, MA 01752	www.hbm.com Tel: (734) 944-4938 or (800) 578-4260 Fax: (508) 485-7480	
Features	Sensor type	Strain gages, force transducers, displacement and acceleration transducers.	
	Data acquisition, processing, and archiving	MGC+ modular data acquisition system (19 in. rack): 24 bit A/D per channel (no time skew between channel); up to 128 input channels; multiple channels can be linked and synchronized together to form hundreds of channels all sampling simultaneously (largest ever tried was 4,012 channels); compatible with most commercially available transducers; signal conditioning modules come in various amplifiers.	
	Communications	Direct wire connections. Remote and/or wireless communication system optional.	
	'Smart' attributes	Software can be setup for real-time, continuous monitoring system with alarm triggering when exceeding predetermined thresholds.	
	Other	CatMan software allows the user to setup, configure, calibrate, display/plot/analyze/collect data; it is a self-contained, stand alone data acquisition package that can be further developed and enhanced by users.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☒ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☒ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☒ Main/secondary cable ☒ Cable anchorage ☒ Anchor rod ☒ Damping system ☒ Strand shoes ☒ Cable bands ☒ Cable enclosures ☐ Other: 2. Movable bridge ☒ Electric brakes ☒ Motors and power ☒ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☒ Crack/fracture	☒ Expansion/contraction	☒ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☐ Section loss	☒ Settlement	☒ Misalignment	☐ Connection failure or deficiencies
☒ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☒ Impact damage
☐ Debonding	☐ Erosion/scour	☐ Looseness and pounding	☐ Excessive joint closing/opening
☐ Corrosion	☒ Environmental	☐ Other:	

Measurement Metric

☒ Strain	☒ Deflection/displacement	☒ Acceleration/vibration	☐ Moisture/humidity level
☒ Temperature	☐ Magnetic field/flux	☒ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☐ Other:	

3. Cost		
Hardware	Sensor	Price depends on sensor capacity and function. Strain gages: $56~$353 per unit. Strain transducers: $424~$1,332 per unit. Compressive force transducers: $450~$13,157 per unit. Compressive/tentile force transducers: $227~$4,516 per unit. Displacement transducers/sensors: $236~$605 per unit. Acceleration transducers: $1,003 per unit.
	Data acquisition system	Price of MGC+ is based on configuration (chassis, communication processor, amplifier cards, etc). A typical 128-channel quarter bridge strain gage system costs a total of $56,784 = one 16 slot housing unit ($1,876) + one display and control panel ($1,310) + one communication processor ($2,702) + sixteen 8-channel amplifier card ($1,647 each) + five connection board with D socket ($1,534 each).
	Communication system	
	Data archiving system	
	Other	Digital PC measurement electronics: $3,316.
Software	CatMan Express (easy data acquisition): $1,162 with $289 for update. CatMan Professional (for measurement, visualization and documentation): $2,944 with $466 for update and $2,213 for upgrade. CatMan Enterprise (for multichannel systems): $7,080 with $2,950 for additional license; $1,770 for additional license for MGC+.	
Labor	Installation	
	Use	
Other: USB adaptor: $176.		

4. Limitations	
Life expectancy	No official life expectancy.
Power	10.5 to 26V DC. 115/230V AC.
Environmental conditions	-10 to 70°C.
Data storage/transfer/ processing	Multi-channel signal conditioning modules can sample at 2,400/4,800/9,600 samples per second per channel, while signal channel can sample at 19,200 samples per second per channel; internal sample clock runs at 76.8 kHz; each channel can have four signal level limits monitored at 38.4 kHz.
Other:	

5. Implementation Needs	
Power source	AC/DC.
Accessibility	Direct access needed for sensor installation. Data can be collected from remote site.
Technical expertise	Moderate training on how to use the system.
Other: Software for computers with Microsoft Windows 98SE/ME/NT4/2000/XP.	

6. Availability

Upon agreement (depending on complexity of the system).

7. On-Going or Completed Bridge Related Projects and References

Information not available.

8. Notes

- HBM has nearly 50 years of experience in manufacturing and supplying strain gages and measurement devices for various applications.
- In addition to analog signals, MGC+ can acquire and process digital data; Canbus data, Profibus data, GPS data, and an intelligent programmable I/O module.
- MGC+ has been used in various locations including laboratories, factory floors, and, with 12/24V operating voltage option, in vehicles for mobile data acquisition.
- A flash memory card or PCMCIA hard drive can be inserted into the system for stand alone operation and storage of data.
- Other features of the MGC+ include the selectable sampling time bases: to reduce the amount of data storage, each MGC+ rack can have up to three time bases allowing the user to sample, for example, thermocouples at a slower rate than an accelerometer or pressure transducer; each time base can have an alternative time base, which is triggered by an event.

1. General Information

Description of Technology	Weldable and bondable strain gages for field measurements.	
Manufacturer and Contact information	Hitec Products, Inc. (HPI) PO Box 790, Ayer, MA 01432	www.hitecprod.com Tel: (978) 772-6963 Fax: (978) 772-6966
Features	Sensor type	Weldable strain gages: precision foil strain gages bonded to strainless steel shim, prewired and waterproofed; precalibrated for thermal output.
	Data acquisition, processing, and archiving	
	Communications	
	'Smart' attributes	
	Other	Also available is polymide bondable gage (where welding is not suggested or permitted).

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☐ Timber:	☐ Plank ☐ Other:	☐ Nailed laminated	☐ Glue-laminated	☐ Prestressed laminated	☐ Stressed timber
	☐ Concrete:	☐ Reinforced ☐ Other:	☐ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☐ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☒ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☐ Abutment:	☐ Footing ☐ Other:	☒ Bridge seat	☐ Piles	☐ Wall (stem/back/wing)	
	☐ Pier/bent/extended pile:	☐ Pier cap ☐ Other:	☐ Shaft	☐ Column/stem	☐ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☐ Main/secondary cable ☒ Cable anchorage ☒ Anchor rod ☒ Damping system ☒ Strand shoes ☒ Cable bands ☒ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☐ Crack/fracture	☐ Expansion/contraction	☐ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☐ Section loss	☐ Settlement	☐ Misalignment	☐ Connection failure or deficiencies
☐ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☐ Impact damage
☐ Debonding	☐ Erosion/scour	☐ Looseness and pounding	☐ Excessive joint closing/opening
☐ Corrosion	☐ Environmental	☐ Other:	

Measurement Metric

☒ Strain	☐ Deflection/displacement	☐ Acceleration/vibration	☐ Moisture/humidity level
☐ Temperature	☐ Magnetic field/flux	☐ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☐ Other:	

3. Cost		
Hardware	Sensor	HBWF35-125-X-10GP (full bridge gage with 10 ft general purpose cable): $164.17. HBW35-125-6-3VR (weldable gage with 3 ft vinyl ribbon lead): $59.06~$75.97. HBWS35-125-6-10GP-NT (weldable shear gage with 10 ft general purpose cable): $92.75.
	Data acquisition system	
	Communication system	
	Data archiving system	
	Other	
Software		
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	No official life expectancy.
Power	Standard: ±9 to 15V DC. Optional: +5 to 15V DC.
Environmental conditions	Up to 80°C
Data storage/transfer/ processing	
Other: Gage resistance: 350 Ohms (standard), 1000 Ohms (optional).	

5. Implementation Needs	
Power source	DC.
Accessibility	Direct access needed for sensor installation.
Technical expertise	Basic skills of sensor installation.
Other:	

6. Availability

2 to 4 weeks for standard products.
25% discount for educational purposes available.

7. On-Going or Completed Bridge Related Projects and References

Detailed information not available; some case studies available on company website.

8. Notes

- All gages from HPI can be built to custom specifications using various configurations and materials.
- Units available to conform to a flat surface or any radius.

1. General Information

Description of Technology	Optical sensing monitoring systeem utilizing Fiber Bragg Grating technology.	
Manufacturer and Contact information	Intelligent Fiber Optic Systems (IFOS) Inc. 650 Vaqueros Ave., Sunnyvale, CA 94085	www.ifos.com Tel: (408) 328-8610 Fax: (408) 328-8614
Features	Sensor type	FBG sensors: Strain, temperature, accelerometer, pressure, inclinometer, seismometer displacement sensors.
	Data acquisition, processing, and archiving	I*Sense 11000, 12000, 14000, 18000 or 160000 interrogation system provides simultaneous data display and storage for each of its channel wavelengths with high measurement bandwidth. All units epuipped with data acquisition software and hardware run with any computer with a MS Windows operating system.
	Communications	Direct connection (fiber) or wireless backhaul transmission/communication.
	'Smart' attributes	Real-time, automated continuous monitoring.
	Other	Up to 16-channel system available. I*Sense is designed to monitor a number of sensors ranging from a few to as many as up to a thousand.

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☒ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☐ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☐ Main/secondary cable ☒ Cable anchorage ☒ Anchor rod ☒ Damping system ☒ Strand shoes ☒ Cable bands ☒ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☒ Crack/fracture	☒ Expansion/contraction	☒ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☐ Section loss	☒ Settlement	☐ Misalignment	☐ Connection failure or deficiencies
☒ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☒ Impact damage
☐ Debonding	☐ Erosion/scour	☐ Looseness and pounding	☐ Excessive joint closing/opening
☒ Corrosion	☒ Environmental	☐ Other:	

Measurement Metric

☒ Strain	☒ Deflection/displacement	☒ Acceleration/vibration	☐ Moisture/humidity level
☒ Temperature	☐ Magnetic field/flux	☐ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☐ Other:	

3. Cost		
Hardware	Sensor	$200~$1,500 per unit
	Data acquisition system	$10,000~$35,000
	Communication system	Included
	Data archiving system	Included
	Other	
Software	$6,000	
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	25 years plus.
Power	85 to 240V AC.
Environmental conditions	-40°C to 125°C.
Data storage/transfer/ processing	Off-the-shelf computer technology used.
Other: Measurand Dynamic Range: 74 dB @ 5 KHz or 90 dB @ 100 Hz for 4-channel; 68 dB @ 5 KHz or 85 dB @ 100 Hz for 8-channel; 62 dB @ 5 KHz or 79 dB @100 Hz for 16-channel system.	

5. Implementation Needs	
Power source	AC.
Accessibility	System can be setup for remote data acquisition and control (remote monitoring system up to 100 km).
Technical expertise	Basic electronics and computer skills, knowledge of fiber optic technology and dynamics.
Other:	

6. Availability

Up to 8 channel/system are available and can be shipped immediately. 16 channel systems will be available in mid-2004.

7. On-Going or Completed Bridge Related Projects and References

Several trial projects in some States and Japan in progress. IFOS does not want to reveal names until complete.
Currently discussing with a Chinese company to place sensing system on their bridges to measure vertical deformation from a horizontal sensing fiber layout.

References:

- Chau, K., Moslehi, B., Song, G., Sethi, V. "Experimental Demonstration of Fiber Bragg Grating Strain Sensors for Structutral Vibration Control," University of Houston, Houston, Texas, July 2004.
- "Reaping the Evanescent Field," The Missle Defense Agency, Winter 2002.
- "Combining Sense and Intelligence for Smarter Structures," SpinOff, National Aeronautics and Space Administration, 40th Anniversary Technology Utilization Program, pp. 80-81, October 2002.

8. Notes

- IFOS started commercial deployments in mid 2003.
- The company designs, develops and manufactures optical sensing systems, photonic modules, fiber optic sensors, wavelength monitoring subsystems; the company offers FBG sensors and Fabry Perot (FP), software, integration, technical support and consulting.
- Other features of IFOS's products include: high sensor sampling speed, intelligent data management to monitor, detect, and assist in decision making; immune to electromagnetic interference; can be multiplexed; low fiber loss with transmission over several kilometers possible; can be used in chemically or electrically explosive environments; automatic calibration; customizable end-user displays.

1. General Information

Description of Technology	Integrated data measurement, acquisition, control and management system; 60+ channel systems.	
Manufacturer and Contact information	IMC Dataworks, LLC 4230 East Towne Blvd., #285, Madison, WI 53704	www.imcdataworks.com Tel: (608) 231-6123 Fax: (608) 244-2284
Features	Sensor type	
	Data acquisition, processing, and archiving	BusDAQ-CANSAS (centralized logging and analysis system). CRONOS-PL (modular measurement system with extensive real-time functionality). IMC system software (automation of any real-time analysis and system response functions as well as display, storage and documentation of results).
	Communications	Direct wire connection or other communication protocols (modem, cell phone, telephone, Fax, PDA, Ethernet, GSM, etc.)
	'Smart' attributes	Network-wide Client/Server operation; Real-time and automation applications; Intelligent storage management; Extensive triggering options; On-board Real-time data analysis.
	Other	SPARTAN: compact multi-channel measuring system specially designed to optimize potential-isolated measurement of voltage and temperature. BR-4 or DCB-8 bridge amplifier also commonly used.

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☐ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☐ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☒ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☒ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☒ Main/secondary cable ☒ Cable anchorage ☒ Anchor rod ☒ Damping system ☒ Strand shoes ☒ Cable bands ☒ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☐ Crack/fracture	☐ Expansion/contraction	☐ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☐ Section loss	☐ Settlement	☐ Misalignment	☐ Connection failure or deficiencies
☐ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☐ Impact damage
☐ Debonding	☐ Erosion/scour	☐ Looseness and pounding	☐ Excessive joint closing/opening
☐ Corrosion	☐ Environmental	☐ Other:	

Measurement Metric

☐ Strain	☐ Deflection/displacement	☐ Acceleration/vibration	☐ Moisture/humidity level
☐ Temperature	☐ Magnetic field/flux	☐ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☐ Other:	

3. Cost		
Hardware	Sensor	
	Data acquisition system	BusDAQ-CANSAS: $5,190. CRONOS-PL3: $8,420. CRONOS-PL8: $14,164. CRONOS-PL16: $15,025.
	Communication system	
	Data archiving system	
	Other	Other systems with more complex configuration available.
Software	Offline analysis software (FAMOS): $1,890~ (per licence); all on-line and configuration software is included.	
Labor	Installation	
	Use	
Other: 12-channel system B: $26,000 including CRONOS-PL3 ($8,420), online processor ($2225), online classification kit ($2,400) and three 4-channel BR-4 modules ($4,215 each) plus accessories. 32-channel system: $27,000 including CRONOS-PL8 ($14,164), four standard bridge inputs, DCB-8 ($2068), online processor ($2,225) and classification kit ($2,400) plus accessories.		

4. Limitations	
Life expectancy	No official life expectancy.
Power	CRONOS PL: 10 to 36V DC, 110/230V AC. CANSAS-Bus 9 to 32V DC.
Environmental conditions	CRONOS PL: 5°C to 40°C, no condensation, 5-95% relative humidity; -20°C to 60°C optional. CANSAS-Bus: -30°C to 65°C, up to 100% air humidity.
Data storage/transfer/ processing	Depends on type of products.
Other:	

5. Implementation Needs	
Power source	AC/DC, solar panel.
Accessibility	Remote data acquisition system.
Technical expertise	Basic electronic and computer skills, knowledge of bridge engineering and dynamics. Moderate training required for system installation and data control and management.
Other: Microsoft Windows 9x/ME, NT/2000, XP or newer version.	

6. Availability

6 to 8 weeks depending on complexity of system.

7. On-Going or Completed Bridge Related Projects and References

Taipei ShinSheng Bridge, Taiwan.
Nan-Foun-Au Bridge, Taiwan.
Ilan Suao Bridge, Taiwan.
Bridge monitoring projects in Spain, Germany and many other countries.

References:

- Wang, C.Y., Chen, C.H., Wang, H.L., and Wu, C.Y. "Development of Bridge Health Monitoring Systems in Taiwan," Center for Bridge Engineering Research, National Central University, Chungli, Taiwan.
- "Structural Engineering Projects: a Sampling from IMC," Presentation-Asian and Euroean Projects 2003, IMC Dataworks, LLC.

8. Notes

- Founded in 1988, IMC DataWorks offers system configuration, application development, and hardware calibration and repair services.
- All systems can be joined together into extended "virtual" systems, which can be synchronized in absolute time; the channel count is practically unlimited (e.g., Two 12-channel systems can work independently at two different test sites, then later be combined to operate as one 24-channel system for a "special" test).
- Analysis of data includes 3-D and X-Y plotting and statistical analysis tools; Programming capabilities include programmable input filtering and Digital Signal Processing, Visual Basic, COM Controls, and Macro-Programming for analysis and automated report generation. Flexible file formats allow users to open and save ASCII, binary, Excel, and many other popular formats.
- Additional features of IMC's products include: all channels can be classified simultaneously; on-line display and storage of time signal and classified data; classification can be controlled by external events (e.g., digital inputs).

1. General Information

Description of Technology	Acoustic instruments for evaluation of concrete and masonry structures.	
Manufacturer and Contact information	Impact-Echo Instruments, LLC. P.O. Box 3871, Ithaca, NY 14852-3871	www.impact-echo.com Tel: (6070 738-1547 Fax: (607) 533-7667*2
Features	Sensor type	Piezo-electric transducer.
	Data acquisition, processing, and archiving	An anallog to digital converter data acquisition system, two channel 14 Bit system, unique to Impact-Echo's hardware and Impact-E software.
	Communications	Direct wire connection.
	'Smart' attributes	Capable of determining thickness of concrete and locating and characterizing defects and flaws.
	Other	Impact-E software guides and controls the monitoring and displays its results in graphical and numerical form.

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☐ Timber:	☐ Plank ☐ Other:	☐ Nailed laminated	☐ Glue-laminated	☐ Prestressed laminated	☐ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☐ Steel:	☐ Grid ☐ Other:	☐ Orthotropic	☐ Buckle plate	☐ Corrugated steel flooring	
	☐ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☐ Channel beam	
	Secondary Element ☐ Connector and fastener: ☐ Bracing: ☐ Diaphragm ☐ Cover plate ☐ Stiffener ☐ Other:	☐ Riveted/bolted ☐ Cross	☐ Welded ☐ Lateral	☐ Pin & hanger ☐ Sway	☐ Splice	
	Bearing ☐ Fixed ☐ Expansion: ☐ Other:	☐ Sliding plate	☐ Roller	☐ Rocker	☐ Pin and link	☐ Elastomeric ☐ Pot ☐ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☐ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☐ Strand shoes 2. Movable bridge ☐ Electric brakes	☐ Main/secondary cable ☐ Cable bands ☐ Motors and power	☐ Cable anchorage ☐ Cable enclosures ☐ Operating machinery and equipment	☐ Anchor rod ☐ Other:	☐ Damping system ☐ Other:	
	Other:					

Monitoring Interest

☒ Crack/fracture	☐ Expansion/contraction	☐ Rotation/torsion	☒ Wear/spalling/scaling/delamination
☐ Section loss	☐ Settlement	☐ Misalignment	☐ Connection failure or deficiencies
☐ Deformation	☒ Wire breakage	☐ Mechanical/electrical malfunction	☒ Impact damage
☒ Debonding	☐ Erosion/scour	☐ Looseness and pounding	☐ Excessive joint closing/opening
☐ Corrosion	☐ Environmental	☒ Other: Honeycombing, locating void and unfilled tendon ducts.	

Measurement Metric

☐ Strain	☐ Deflection/displacement	☐ Acceleration/vibration	☐ Moisture/humidity level
☐ Temperature	☐ Magnetic field/flux	☐ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☒ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☐ Other:	

3. Cost		
Hardware	Sensor	
	Data acquisition system	
	Communication system	
	Data archiving system	
	Other	$10,500 for total system except computer.
Software	Included.	
Labor	Installation	
	Use	Minimal cost for maintenance and operation.
Other:		

4. Limitations	
Life expectancy	No official life expectancy (unlimited if used with care).
Power	110/220V AC, or 12V DC
Environmental conditions	Operatable in most environments (not under water).
Data storage/transfer/ processing	
Other:	

5. Implementation Needs	
Power source	Battery, AC/DC.
Accessibility	Direct access needed for data measurement.
Technical expertise	Minimal training on equipment with basic computer skills required.
Other: IBM-compatible computer with Windows 95 or later operating system; 100 MHz or faster processor; 16 MB RAM.	

6. Availability

Readily available.

7. On-Going or Completed Bridge Related Projects and References

Crack Monitoring in Deck of Reinforced Concrete Railway Bridge, Denmark
Measuring Thickness of Concrete Pavement in New Highway Test Section, Arizona
Locating Voids in Grouted Tendon Ducts of a Post-Tensioned Highway Bridge, Northeastern USA.
Monitoring of Delaminations in Concrete Bridge Deck with Asphalt Overlay, New York State, USA.
Used on numerous bridge monitoring projects over 10 years by many engineering companies, universities, governmental agencies in many countries.

Reference:
• Sansalone, M.J., and Streett, W.B. "Impact-Echo:Nondestructive Evaluation of Concrete and Masonry". Bullbrier Press (1997) 339pp.
• Several case studies and references are available on company website.

8. Notes

• Impact-Echo Instruments, LLC was founded in 1997; the impact-echo test instruments are based on research carried out at the U.S. National Institute of Standards and Technology (NIST) and Cornell University by Professor M. Sansalone, the principal inventor of the method; the first portable, computer-controlled, impact-echo field instrument was developed at Cornell University in the early 1990's.
• Features of the Impact-Echo system includes: measurement is not adversely affected by the presence of steel reinforcing bars; a single transducer is used for routine testing; two transducers separated by a fixed distance are used for independent measurements of wave speed.
• Applications include:
1. Measure thickness of concrete slabs according to ASTM Standard C 1383-98a, including pavements, retaining walls, tunnel walls, etc.;
2. Determine location, depth and extent of cracks, voids, delaminations, honeycombing and debonding in plain and reinforced structures, including plates (slabs, walls, decks, pavements), layered plates (including asphalt on concrete), columns and beams (round, square, rectangular), and hollow cylinders (pipes, tunnels, mineshaft liners, tanks).
3. Locate voids in subgrade beneath slabs and pavements;
4. Measure depth of surface-opening cracks;
5. Locate voids in the grouting in tendon ducts in post-tensioned structures;
6. Locate cracks, voids and other defects in masonry structures where brick or block units are bonded together by mortar.

1. General Information

Description of Technology	Ground Penetrating Radar (GPR) and Infrared thermography (IR) monitoring system.	
Manufacturer and Contact information	Infrasense, Inc. 14 Kensington Road, Arlington, MA 02476	www.infrasense.com Tel: (781)-648-0440 Fax: (781) 648-1778
Features	Sensor type	Air-coupled or ground-coupled radio wave antennas for data interpretation, infrared thermography and video camera.
	Data acquisition, processing, and archiving	Laptop computer with a Windows-based GRP data analysis software, DECAR. Infrasense Analytical IR Viewing Station for data monitoring.
	Communications	
	'Smart' attributes	Simultaneous recordings of infrared and visual observations
	Other	Anomalies are recorded into the computer database for analysis. The digitized data is adapted for CAD output.

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☐ Truss ☐ Arch
☐ Rigid Frame ☐ Suspension ☐ Cable-stayed ☐ Vertical lift
☐ Swing ☐ Bascule ☐ Other:

Bridge Component

Deck	☐ Timber:	☐ Plank ☐ Nailed laminated ☐ Glue-laminated ☐ Prestressed laminated ☐ Stressed timber ☐ Other:
	☒ Concrete:	☒ Reinforced ☒ Prestressed/post-tensioned ☐ Other:
	☐ Steel:	☐ Grid ☐ Orthotropic ☐ Buckle plate ☐ Corrugated steel flooring ☐ Other:
	☐ FRP:	
Superstructure	*Primary Element*	☐ Multi-beam/girder system: ☐ Girder floor beam/diaphragm system ☐ Tee beam ☐ Box girder ☐ Channel beam ☒ Slab ☐ Truss member ☐ Arch element ☐ Other:
	Secondary Element	☐ Connector and fastener: ☐ Riveted/bolted ☐ Welded ☐ Pin & hanger ☐ Splice ☐ Bracing: ☐ Cross ☐ Lateral ☐ Sway ☐ Diaphragm ☐ Cover plate ☐ Stiffener ☐ Other:
	Bearing	☐ Fixed ☐ Expansion: ☐ Sliding plate ☐ Roller ☐ Rocker ☐ Pin and link ☐ Elastomeric ☐ Pot ☐ Restraining ☐ Other:
	Other:	
Substructure	☐ Abutment:	☐ Footing ☐ Bridge seat ☐ Piles ☐ Wall (stem/back/wing) ☐ Other:
	☐ Pier/bent/extended pile:	☐ Pier cap ☐ Shaft ☐ Column/stem ☐ Submerged pile/pile cap/footing ☐ Other:
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)*	1. Cable-supported bridge ☐ Tower ☐ Main/secondary cable ☐ Cable anchorage ☐ Anchor rod ☐ Damping system ☐ Strand shoes ☐ Cable bands ☐ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:
	Other:	

Monitoring Interest

☒ Crack/fracture	☐ Expansion/contraction	☐ Rotation/torsion	☒ Wear/spalling/scaling/delamination
☐ Section loss	☐ Settlement	☐ Misalignment	☐ Connection failure or deficiencies
☐ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☐ Impact damage
☒ Debonding	☐ Erosion/scour	☐ Looseness and pounding	☐ Excessive joint closing/opening
☒ Corrosion	☐ Environmental	☒ Other: freeze-thaw effect.	

Measurement Metric

☐ Strain	☐ Deflection/displacement	☐ Acceleration/vibration	☐ Moisture/humidity level
☐ Temperature	☐ Magnetic field/flux	☐ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☒ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☐ Other:	

3. Cost		
Hardware	Sensor	$50,000/unit
	Data acquisition system	
	Communication system	
	Data archiving system	
	Other	
Software	$15,000.	
Labor	Installation	Vehicle-based.
	Use	
Other:		

4. Limitations	
Life expectancy	
Power	
Environmental conditions	
Data storage/transfer/ processing	
Other:	

5. Implementation Needs	
Power source	
Accessibility	
Technical expertise	
Other:	

6. Availability

Upon agreement.

7. On-Going or Completed Bridge Related Projects and References

Tappan Zee Bridge, NY
Grand Island Bridge, NY
Rouge River Bridge, MI
Tongass Avenue and Water Street Viaducts in Ketchikan, Alaska.
A statewide bridge deck GPR survery by the Arizona Department of Transportation.
Numerous projects in over 42 United States, in Canada, and countries in Europe, the Middle East, and Asia.

References:

- Maser, K.R., Roberts, R., Kutrubes, D., and Holland, T.J. "Technology for Quality Assurance of New Pavement Thickness," ASNT Conference, NDE/NDT for Highways and Bridges, Cincinnati, OH, September 2002.
- Briggs, R.C., Scullion, T., and Maser, K.R. "Use of Radar Technology for Pavement Layer Evaluation," Proceedings of the 7th International Conference on Asphalt Pavements, pp. 245-260, 1998.
- Fippinger, F., Maser, K.R., Kristiansen, J., and Schellenberger, W. "Evaluation of Pavement Thickness using Ground Penetrating Radar," Proceedings of the International Symposium of Nondestructive Testing in Civil Engineering, Berlin Germany, 26-28 Sept., 1995.
- Several references are available on company website.

8. Notes

- Incorporated in 1987, INFRASENSE specializes in GPR bridge deck and pavement surveys as well as the design, development, and implementation of numerous non-destructive (NDE) evaluations and measurement programs and surveys for civil engineering.
- Some features and application of GPR monitoring system include: computation for depth of reinforcement; evaluation of deterioration quantities; measurement of overlay thickness; quality control of reinforcing bar placement.

1. General Information

Description of Technology	Continuous and transient vibrations and overpressure monitoring technology.		
Manufacturer and Contact information	Instantel 309 Legget Dr., Ottawa, Ontario, Canada, K2K 3A3	www.instantel.com Tel: (613) 592-4642 Fax:(613) 592-4296	
Features	Sensor type	Velocity sensors (geophones), Accelerometers, Microphones and overpressure sensors.	
	Data acquisition, processing, and archiving	Blastmate: rugged, self-contained package with storage compartment for sensors and accessories; rechargeable gel battery with 30-day capacity; 4-8 channels data acquisition. Minimate: small, portable, rugged package and easy setup. Instantel Blastware Software: vibration event management, reporting and advanced data analysis software; designed to perform several tasks to assist with monitoring operations.	
	Communications	Direct wire connection. Optional remote communication system: RF, Celluar phones, Pagers, PDA's, Internet, Satellite and short haul modems.	
	'Smart' attributes	Real-time, continuous vibration and overpressure monitoring; system can be designed or setup to automatically collect data, sent wirelessly to a central location for processing and alert engineers in case of emergency.	
	Other	System is capable of monitoring for extended periods of time, remotely monitoring with automatic storing of data to a PC, triggering external alarms, and programming sample rate to increase the frequency response.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☐ Timber: ☐ Plank ☐ Nailed laminated ☐ Glue-laminated ☐ Prestressed laminated ☐ Stressed timber ☐ Other:	
	☐ Concrete: ☐ Reinforced ☐ Prestressed/post-tensioned ☐ Other:	
	☐ Steel: ☐ Grid ☐ Orthotropic ☐ Buckle plate ☐ Corrugated steel flooring ☐ Other:	
	☐ FRP:	
Superstructure	*Primary Element* ☐ Multi-beam/girder system: ☐ Girder floor beam/diaphragm system ☐ Tee beam ☐ Box girder ☐ Channel beam ☐ Slab ☐ Truss member ☐ Arch element ☐ Other:	
	Secondary Element ☐ Connector and fastener: ☐ Riveted/bolted ☐ Welded ☐ Pin & hanger ☐ Splice ☐ Bracing: ☐ Cross ☐ Lateral ☐ Sway ☐ Diaphragm ☐ Cover plate ☐ Stiffener ☐ Other:	
	Bearing ☐ Fixed ☐ Expansion: ☐ Sliding plate ☐ Roller ☐ Rocker ☐ Pin and link ☐ Elastomeric ☐ Pot ☐ Restraining ☐ Other:	
	Other:	
Substructure	☐ Abutment: ☐ Footing ☐ Bridge seat ☐ Piles ☐ Wall (stem/back/wing) ☐ Other:	
	☐ Pier/bent/extended pile: ☐ Pier cap ☐ Shaft ☐ Column/stem ☐ Submerged pile/pile cap/footing ☐ Other:	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☐ Tower ☐ Main/secondary cable ☐ Cable anchorage ☐ Anchor rod ☐ Damping system ☐ Strand shoes ☐ Cable bands ☐ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:	
	Other:	

Monitoring Interest

☐ Crack/fracture ☐ Expansion/contraction ☐ Rotation/torsion ☐ Wear/spalling/scaling/delamination
☐ Section loss ☐ Settlement ☐ Misalignment ☐ Connection failure or deficiencies
☐ Deformation ☐ Wire breakage ☐ Mechanical/electrical malfunction ☒ Impact damage
☐ Debonding ☐ Erosion/scour ☐ Looseness and pounding ☐ Excessive joint closing/opening
☐ Corrosion ☐ Environmental ☒ Other: Blast monitoring; construction or demolition activity, pile driving.

Measurement Metric

☐ Strain ☐ Deflection/displacement ☒ Acceleration/vibration ☐ Moisture/humidity level
☐ Temperature ☐ Magnetic field/flux ☐ Electrical voltage/current ☐ Chemical composition
☐ Radar waves ☐ Acoustic waves ☐ Magnetic waves ☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☐ Wind speed/direction ☒ Other: Sound measurement.

3. Cost		
Hardware	Sensor	Accelerometers (requires acclerometer adaptor and accelerometer cable): $559 (500g), $629 (50g) Triaxial geophone with 2m (6 ft) cable: $695. Linear microhone assembly with 2m (6 ft) cable: $495. Uniaxial geophone with 5m (15 ft) cable: $299 (vertical), $389 (horizontal). Borehole triaxial geophone with 30m (100 ft) cable: $879.
	Data acquisition system	Minimate system (standard triaxial geophone, linear microphone assembly, RS-232 cable, Blastware Compliance software, AC power adaptor, manual, and carrying case): $2,895. Minimate Plus system (base unit, standard triaxial geophone, linear microphone assembly, RS-232 cable, Blastware Compliance software, AC power adaptor, manual, and carrying case): $5,295. Blastmate II system (standard triaxial geophone, linear microphone assembly, RS-232 cable, plotter, Blastware Compliance software, AC power adaptor, manual, 1 set of 3 pens, and 3 rolls of paper): $5,495. Blastmate III system (base unit, standard triaxial geophone, linear microphone assembly, RS-232 cable, Blastware Compliance software, AC power adaptor, manual, and 3 rolls of paper): $6,995.
	Communication system	
	Data archiving system	
	Other	Triaxial accelerometer mounting block (for use with 50g and 500g acclerometers): $369. Accelerometer adaptor cable (for use with 50g and 500g acclerometers; 3m, 10 ft): $ 149. Extra 1200 event capacity upgrade (for Blastmate III or Minimate Plus): $1,495. Extra 4 channels (to make the system a total of 8 channels): $1,798.
Software	Blastware Compliance Module software (event management and reporting software, complete with manual): $99. Blastware Advanced Module software (event management, reporting, and advanced analysis software complete with manual): $699.	
Labor	Installation	
	Use	
Other: Extension cable line driver: $379 (30 m; 100 ft), $429 (75 m; 250 ft). 12V battery/power supply cable: $99. Primary/secondary trigger cable: $89. Remote alarm controller: $699. Remote alarm/RS-232 splitter cable: $149. DS-20 wire break trigger package: $79. Universal breakout box: $459. Universal mounting block kit: $89. USB serial adaptor cable: $89. 110V or 220V AC adaptor: $29.		

4. Limitations	
Life expectancy	No official life expectancy.
Power	Rechargeable 6V sealed gel cell battery (for 30 days continuous monitoring). 110/220V AC.
Environmental conditions	-10 to 50°C.
Data storage/transfer/ processing	Blastmate: vibration monitoring range of up to 254 mm/s; frequency range from 2 to 250 Hz; 40 event storage capacity (optional 300 event storage capacity); histogram recording interval at 5 sec, 15 sec, 1 min or 5 min. Minimate: vibration monitoring range of up to 127 mm/s (254 mm for Minimate Plus); air overpressure monitoring range from 100 to 142 dB; frequency range from 2 to 250 Hz.
Other: PC interface: RS-232.	

5. Implementation Needs	
Power source	Battery, AC, solar panel.
Accessibility	Remote data acquisition and control.
Technical expertise	Minimal training. Technical support available on-line or by phone.
Other: Microsoft Windows 98, 2000 or XP operating system required.	

6. Availability
2 to 7 weeks.

7. On-Going or Completed Bridge Related Projects and References
Sungai Prai Cable Stay Bridge Penang, Malaysia. Several case studies available on company website.

8. Notes
• Instantel was founded in 1982 and their technologies are certified to the ISO 9001 Quality Standard. • Instantel's products and technologies are mostly used for monitoring blast and pile driving effects during construction/demolition.

1. General Information

Description of Technology	Fast location of pre- and post-tensioning steel fractures and the degree of damage in bridge decks and other concrete structures using the Remanent Magnetism (RM) Method.	
Manufacturer and Contact information	Institute of Civil Engineering, Technische Universitat Berlin Sekr, TIB 1-B4, Gustav-Meyer-Allee25, Berlin, Germany	www.tu-berlin.de/eng/ Tel: 314 72101 Fax: 314-72110
Features	Sensor type	Manetic sensors (probes): sensors cover a range from 1μT to 300μT (or more) to measure the residual field of magnetized tendons at the concrete surface.
	Data acquisition, processing, and archiving	A 12-bit resolution; 7.5 kB/s of maximum data acquisition rate (sensor-array with 512 sensors). Data acquisition does not limit the measuring speed. Data processing consists of a routine that locates the magnetic poles of the tendon sections and relates them to find position.
	Communications	
	'Smart' attributes	
	Other	More sensors or a higher resolution along the measuring path are possible if desired.

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☐ Timber: ☐ Plank ☐ Nailed laminated ☐ Glue-laminated ☐ Prestressed laminated ☐ Stressed timber ☐ Other:	
	☒ Concrete: ☒ Reinforced ☒ Prestressed/post-tensioned ☐ Other:	
	☐ Steel: ☐ Grid ☐ Orthotropic ☐ Buckle plate ☐ Corrugated steel flooring ☐ Other:	
	☐ FRP:	
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Girder floor beam/diaphragm system ☒ Tee beam ☒ Box girder ☒ Channel beam ☒ Slab ☐ Truss member ☐ Arch element ☐ Other:	
	Secondary Element ☐ Connector and fastener: ☐ Riveted/bolted ☐ Welded ☐ Pin & hanger ☐ Splice ☐ Bracing: ☐ Cross ☐ Lateral ☐ Sway ☐ Diaphragm ☐ Cover plate ☐ Stiffener ☐ Other:	
	Bearing ☐ Fixed ☐ Expansion: ☐ Sliding plate ☐ Roller ☐ Rocker ☐ Pin and link ☐ Elastomeric ☐ Pot ☐ Restraining ☐ Other:	
	Other:	
Substructure	☐ Abutment: ☐ Footing ☐ Bridge seat ☐ Piles ☐ Wall (stem/back/wing) ☐ Other:	
	☐ Pier/bent/extended pile: ☐ Pier cap ☐ Shaft ☐ Column/stem ☐ Submerged pile/pile cap/footing ☐ Other:	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☐ Tower ☐ Main/secondary cable ☐ Cable anchorage ☐ Anchor rod ☐ Damping system ☐ Strand shoes ☐ Cable bands ☐ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:	
	Other:	

Monitoring Interest

☒ Crack/fracture ☐ Expansion/contraction ☐ Rotation/torsion ☐ Wear/spalling/scaling/delamination
☐ Section loss ☐ Settlement ☐ Misalignment ☐ Connection failure or deficiencies
☐ Deformation ☒ Wire breakage ☐ Mechanical/electrical malfunction ☒ Impact damage
☐ Debonding ☐ Erosion/scour ☐ Looseness and pounding ☐ Excessive joint closing/opening
☐ Corrosion ☐ Environmental ☐ Other:

Measurement Metric

☐ Strain ☐ Deflection/displacement ☐ Acceleration/vibration ☐ Moisture/humidity level
☐ Temperature ☒ Magnetic field/flux ☐ Electrical voltage/current ☐ Chemical composition
☐ Radar waves ☐ Acoustic waves ☐ Magnetic waves ☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☐ Wind speed/direction ☐ Other:

3. Cost		
Hardware	Sensor	
	Data acquisition system	
	Communication system	
	Data archiving system	
	Other	
Software		
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	
Power	
Environmental conditions	
Data storage/transfer/ processing	
Other:	

5. Implementation Needs	
Power source	
Accessibility	
Technical expertise	
Other:	

6. Availability

The method has been applied on full size bonded and unbonded pre- and post-tensioned bridge and building structures.
Further development is currently underway to improve the feasibility.

7. On-Going or Completed Bridge Related Projects and References

Reference:

- Scheel, H., and Hillemeier, B. "Location of Prestressing Steel Fractures in Concrete," The Journal of Materials in Civil Engineering, Vol. 15, No. 3, June 2003.
- Scheel, H., and Hillemeier, B. "Fast Location of Prestressing Steel Fractures in Bridge Decks and Parking Lots," Non-Destructive Testing in Civil Engineering 2003, International Symposium (NDE-CE 2003), Berlin, Germany, September 16-19, 2003.

8. Notes

- In practice, the limitations of the RM-Method depend mainly on the density and regularity of mild reinforcement and on the minimum degree of damage that is to be detected.
- The RM-method is capable of penetrating a concrete cover of up to 30 cm.
- The testing of tendons can be performed from the vertical surface (with different setup that is used for bridge deck monitoring) or from the top surface of concrete structure.
- In Spring 2004, a vehicle to drive the measurement devices was being developed; upon completion of the sensor-array and the vehicle carrying the measurement devices, a field test was scheduled to optimize the measuring speed of the system and to develop methods for the physical and numerical suppression of interfering signals.

1. General Information

Description of Technology	SmartCET intelligent corrosion monitoring for reinforced concrete structure; online, real-time monitoring of corrosion rate and pitting.		
Manufacturer and Contact information	InterCorr International, Inc 14503 Bammel N. Houston, Suite 300, Houston, Texas 77014	www.intercorr.com Tel: (281) 444-2282 Fax: (281) 444-0246	
Features	Sensor type	Standard electrode probes.	
	Data acquisition, processing, and archiving	SmartCET™ is an IS-certified field corrosion monitoring unit; it is installed directly adjacent to a corrosion probe. Three-pair cabling is used to connect the SmartCET™ system to the probe; two SmartCET™ units can be linked on a single communications loop; the system can support up to a total of 16 SmartCET™ units. The FieldCET software is used for data acquisition and trending purposes.	
	Communications	1-16 channel modem system. Device is addressable and able to communicate using a variety of serial protocols (proprietary RS485 and HART) up to a maximum hardwired distance of 1,200 meters (approx. 3,900 ft).	
	'Smart' attributes	Online, real-time monitoring of corrosion rate and pitting. Capable of monitoring localized (pitting) corrosion along with general corrsion. Alarm system is available.	
	Other	System measures and anlyzes the elctrochemical response of the probe using high-resolution analog-to-digital and digital-to-analog converters under local micro-processor control.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☐ Timber:	☐ Plank ☐ Other:	☐ Nailed laminated	☐ Glue-laminated	☐ Prestressed laminated	☐ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☐ Steel:	☐ Grid ☐ Other:	☐ Orthotropic	☐ Buckle plate	☐ Corrugated steel flooring	
	☐ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☐ Channel beam	
	Secondary Element ☐ Connector and fastener: ☐ Bracing: ☐ Diaphragm ☐ Cover plate ☐ Stiffener ☐ Other:	☐ Riveted/bolted ☐ Cross	☐ Welded ☐ Lateral	☐ Pin & hanger ☐ Sway	☐ Splice	
	Bearing ☐ Fixed ☐ Expansion: ☐ Other:	☐ Sliding plate	☐ Roller	☐ Rocker	☐ Pin and link	☐ Elastomeric ☐ Pot ☐ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☒ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☐ Strand shoes 2. Movable bridge ☐ Electric brakes	☐ Main/secondary cable ☐ Cable bands ☐ Motors and power	☐ Cable anchorage ☐ Cable enclosures ☐ Operating machinery and equipment	☐ Anchor rod ☐ Other:	☐ Damping system ☐ Other:	
	Other:					

Monitoring Interest

☐ Crack/fracture	☐ Expansion/contraction	☐ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☐ Section loss	☐ Settlement	☐ Misalignment	☐ Connection failure or deficiencies
☐ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☐ Impact damage
☐ Debonding	☐ Erosion/scour	☐ Looseness and pounding	☐ Excessive joint closing/opening
☒ Corrosion	☐ Environmental	☐ Other:	

Measurement Metric

☐ Strain	☐ Deflection/displacement	☐ Acceleration/vibration	☒ Moisture/humidity level
☒ Temperature	☐ Magnetic field/flux	☒ Electrical voltage/current	☒ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☐ Other:	

3. Cost		
Hardware	Sensor	Variable depending on type of sensors: approximately $500 per unit.
	Data acquisition system	SmartCET device: $4,500 per unit.
	Communication system	
	Data archiving system	
	Other	
Software	FieldCET software: $4,500.	
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	No official life expectancy.
Power	18 to 36V DC, 110/220V AC.
Environmental conditions	-45°C to 85°C
Data storage/transfer/ processing	
Other:	

5. Implementation Needs	
Power source	AC/DC, solar panel.
Accessibility	Direct access needed for sensor installation. Remote monitoring and control.
Technical expertise	Minimal training. Basic electronic skills.
Other:	

6. Availability

Readily available.

7. On-Going or Completed Bridge Related Projects and References

Has not been used on bridge structures.

8. Notes

- For over 20 years, Intercorr has served many clients in 32 countries; the company specialties in corrosion monitoring instrumentation, testing and consulting services, developing predictive software and corrosion research.
- Units offer multi-technique monitoring capabilities and can be programmed on-site to operate in several modes for combined electrochemical monitoring, galvanic current monitoring and hydrogen permeation monitoring.
- The instrument connects locally to the corrosion probe (typically within 15ft) and acquires and pre-processes data over an automated 430-second measurement cycle. A data packet of 13 values is delivered to the host computer at the end of each cycle where material-specific constants are used to calculate output values such as general corrosion rate, Pitting Factor, anodic and cathodic Tafel slopes and the Stern-Geary constant, also skewness and kurtosis of current and potential noise signals.

1. General Information

Description of Technology	Micro-Miniature Wireless Instrumentation System (MicroWIS); MEMS technologies for wireless structural health monitoring.	
Manufacturer and Contact information	Invocon, Inc. 19221 IH 45 South, Suite 530, Conroe, TX 77385	www.invocon.com Tel: (281) 292-9903 Fax: (281) 298-1717
Features	Sensor type	Strain gages, pressure sensors, humidity sensors, accelerometers, or any other sensor with an active resistive element.
	Data acquisition, processing, and archiving	Wireless data acquisition system for structural monitoring and evaluation (SMES) or wireless Ethernet-based data acquisition system. MITE WIS: capable of transmitting real-time data from up to four channels. MicroSAFE system: processes strain data with the ASTM Rainflow Cycle Counting Algorithm at the remote sensor location.
	Communications	RF radio, cell phone, Ethernet, Internet, etc.
	'Smart' attributes	Real-time, wireless, continuous monitoring with optional alarm triggering system.
	Other	A combination of MicroWIS-XG and CellWIS provides near-static strain measurements remotely to the user on his/her computer.

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☒ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☐ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☐ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☐ Main/secondary cable ☒ Cable anchorage ☐ Anchor rod ☒ Damping system ☒ Strand shoes ☒ Cable bands ☒ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☐ Crack/fracture	☐ Expansion/contraction	☐ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☐ Section loss	☐ Settlement	☐ Misalignment	☐ Connection failure or deficiencies
☐ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☒ Impact damage
☐ Debonding	☐ Erosion/scour	☐ Looseness and pounding	☐ Excessive joint closing/opening
☐ Corrosion	☐ Environmental	☒ Other: Stress analysis.	

Measurement Metric

☒ Strain	☒ Deflection/displacement	☒ Acceleration/vibration	☒ Moisture/humidity level
☒ Temperature	☐ Magnetic field/flux	☐ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☒ Other:	

3. Cost		
Hardware	Sensor	$500~$2,000/channel (not including transducer) depending on type of product.
	Data acquisition system	Variable depending on number of channel. Some are included in sensor system.
	Communication system	$2,500~ (wireless receiver that attaches to a PC with a graphical user interface software.
	Data archiving system	
	Other	1 year warranty for hardware.
Software	Included.	
Labor	Installation	Only the time to install the wireless sensors. No need to run wires.
	Use	
Other:		

4. Limitations	
Life expectancy	No official life expectancy.
Power	Battery powered, 2.8 to 4.0V input range. Standard external batteries for continuous 24-hr acquisition for over 45 days (MicroSAFE). Various size of batteries are available.
Environmental conditions	Typically -35°C to 85°C. According to Invocon, their products can operate in most terrestrial environments and temperatures.
Data storage/transfer/ processing	
Other:	

5. Implementation Needs	
Power source	Battery.
Accessibility	Remote data acquisition and control.
Technical expertise	Minimal training. Basic electronic skills. Knowledge of bridge engineering and dynamics. Application engineers are available for common technical issues by phone.
Other:	

6. Availability

Generally 4 to 6 weeks. For customized design or complicated systems, 10 to 12 weeks.
Some devices and pieces of equipment are available for rental.

7. On-Going or Completed Bridge Related Projects and References

Box girder overpass in Huston, Texas (testing during construction and monitoring performed).
Some case studies and references are available on company website.

8. Notes

- Founded in 1986, Invocon is a R&D company, developing new technologies, systems, and ideas for new applications, with different parameters; has produced high technology design and prototype fabrication for major corporations, professional R&D management companies, and government entities.
- Invocon's sensors can be modified to interface with most any type of transducer: strain, pressure, acceleration, temperature, etc.
- Invocon's monitoring system is capable of providing information that indicates the current state of the test element or structure, and trend data that indicates the likely future state of the test element or structure.
- The company offers custom designed products to meet specific applications (based on required bandwidth, power consumption, available networking, acceptable latency, required synchronization, operating environment, etc.).

1. General Information

Description of Technology	Ethernet-based portable high-speed waveform data acquisition system for pile monitoring.		
Manufacturer and Contact information	IOtech, Inc. 25971 Cannon Road, Cleveland, OH 44146	www.iotech.com Tel: (440) 439-4091 Fax: (440) 439-4093	
Features	Sensor type	Does not provide sensors. The system is normally used with accelerormeter; also suitable with voltage senosrs, strain gages, thermocouples, and other signal types.	
	Data acquisition, processing, and archiving	WaveBook/516 digitizer (multi-channel waveform acquisition and analysis): 8 built-in channels expandable up to 72 channels. WaveView software: easy setup, time-domain waveform viewing, and real-time storage of acquired data to disk. eZ-PostView software: visually scroll through multiple waveforms on PC screen.	
	Communications	Direct wire connection.	
	'Smart' attributes		
	Other	For application beyond 72 channels, up to four WaveBooks can be combined within one measurement system, for a total capacity of 288 channels.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☐ Timber: ☐ Plank ☐ Nailed laminated ☐ Glue-laminated ☐ Prestressed laminated ☐ Stressed timber ☐ Other:	
	☐ Concrete: ☐ Reinforced ☐ Prestressed/post-tensioned ☐ Other:	
	☐ Steel: ☐ Grid ☐ Orthotropic ☐ Buckle plate ☐ Corrugated steel flooring ☐ Other:	
	☐ FRP:	
Superstructure	*Primary Element* ☐ Multi-beam/girder system: ☐ Girder floor beam/diaphragm system ☐ Tee beam ☐ Box girder ☐ Channel beam ☐ Slab ☐ Truss member ☐ Arch element ☐ Other:	
	Secondary Element ☐ Connector and fastener: ☐ Riveted/bolted ☐ Welded ☐ Pin & hanger ☐ Splice ☐ Bracing: ☐ Cross ☐ Lateral ☐ Sway ☐ Diaphragm ☐ Cover plate ☐ Stiffener ☐ Other:	
	Bearing ☐ Fixed ☐ Expansion: ☐ Sliding plate ☐ Roller ☐ Rocker ☐ Pin and link ☐ Elastomeric ☐ Pot ☐ Restraining ☐ Other:	
	Other:	
Substructure	☒ Abutment: ☐ Footing ☐ Bridge seat ☒ Piles ☐ Wall (stem/back/wing) ☐ Other:	
	☒ Pier/bent/extended pile: ☐ Pier cap ☐ Shaft ☐ Column/stem ☒ Submerged pile/pile cap/footing ☒ Other: Piles	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☐ Tower ☐ Main/secondary cable ☐ Cable anchorage ☐ Anchor rod ☐ Damping system ☐ Strand shoes ☐ Cable bands ☐ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:	
	Other:	

Monitoring Interest

☐ Crack/fracture ☐ Expansion/contraction ☐ Rotation/torsion ☐ Wear/spalling/scaling/delamination
☐ Section loss ☐ Settlement ☐ Misalignment ☐ Connection failure or deficiencies
☐ Deformation ☐ Wire breakage ☐ Mechanical/electrical malfunction ☐ Impact damage
☐ Debonding ☐ Erosion/scour ☐ Looseness and pounding ☐ Excessive joint closing/opening
☐ Corrosion ☐ Environmental ☒ Other: piling length.

Measurement Metric

☐ Strain ☐ Deflection/displacement ☒ Acceleration/vibration ☐ Moisture/humidity level
☐ Temperature ☐ Magnetic field/flux ☐ Electrical voltage/current ☐ Chemical composition
☐ Radar waves ☐ Acoustic waves ☐ Magnetic waves ☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☐ Wind speed/direction ☐ Other:

3. Cost		
Hardware	Sensor	
	Data acquisition system	WaveBook/516E Premium: $6,000. Price varies based on specification and capability.
	Communication system	
	Data archiving system	
	Other	DBK30A Rechargeable battery/excitation module: $649.
Software	Included.	
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	No official life expectancy.
Power	Power consumption: 1.8A max @ 1.5V DC. Input power range: 10 to 30V DC.
Environmental conditions	Operating temperature: 0 to 50°C. Humidity: 0 to 95% RH, non condensing.
Data storage/transfer/ processing	Notebook PC.
Other: Frequency and pulse counting inputs up to 1 MHz.	

5. Implementation Needs	
Power source	Battery, DC.
Accessibility	Direct access needed for data acquisition.
Technical expertise	Minimal training. Basic electronic skills.
Other:	

6. Availability
Agreement by order.

7. On-Going or Completed Bridge Related Projects and References
Information not available.

8. Notes
• Founded in 1985, IOtech, Inc. designs and manufactures PC-based data acquisition and measurement instrumentation. • The system can be used as a nondestructive solution to determine the support-piling length; the user places a data acquisition system adjacent to the support piling and attaches two ICP-style accelerometers on the structure at a fixed distance from one another. Using a radio-controlled mechanical mallet, the user taps the support piling to create wave-front vibrations. The data acquisition equipment then tracks the travel and reflection of the wave fronts via the two attached accelerometers.

1. General Information

Description of Technology	Smart Aggregate: wireless embedded sensor flatform (WESP) technology for corrosion monitoring.	
Manufacturer and Contact information	Johns Hopkins University Applied Physics Laboratory (APL) 11100 Johns Hopkins Road, Laurel, Maryland 20723-6099	www.jhuapl.edu Tel: (240) 228-8309, John Bacon or (240)-228-5000
Features	Sensor type	Smart Aggregate (wireless embeddable sensor, roughly the size of a quarter): can be embedded during concrete placement.
	Data acquisition, processing, and archiving	The data reader, which can be mounted on car or truck, powers the Smart Aggregates as it passes over them and stores the sensor data into a PC.
	Communications	
	'Smart' attributes	
	Other	Each sensor contains wireless power receiver and data transmission coils and is designed using ceramic hybrid integrated circuit technology to withstand mechanical stresses and the high pH environment of concrete.

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☐ Timber:	☐ Plank ☐ Nailed laminated ☐ Glue-laminated ☐ Prestressed laminated ☐ Stressed timber ☐ Other:
	☒ Concrete:	☒ Reinforced ☒ Prestressed/post-tensioned ☐ Other:
	☐ Steel:	☐ Grid ☐ Orthotropic ☐ Buckle plate ☐ Corrugated steel flooring ☐ Other:
	☐ FRP:	
Superstructure	*Primary Element*	☒ Multi-beam/girder system: ☒ Girder floor beam/diaphragm system ☒ Tee beam ☒ Box girder ☒ Channel beam ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:
	Secondary Element	☐ Connector and fastener: ☐ Riveted/bolted ☐ Welded ☐ Pin & hanger ☒ Splice ☒ Bracing: ☐ Cross ☐ Lateral ☐ Sway ☒ Diaphragm ☐ Cover plate ☐ Stiffener ☐ Other:
	Bearing	☐ Fixed ☐ Expansion: ☐ Sliding plate ☐ Roller ☐ Rocker ☐ Pin and link ☐ Elastomeric ☐ Pot ☐ Restraining ☐ Other:
	Other:	
Substructure	☒ Abutment:	☒ Footing ☒ Bridge seat ☒ Piles ☒ Wall (stem/back/wing) ☐ Other:
	☒ Pier/bent/extended pile:	☒ Pier cap ☒ Shaft ☒ Column/stem ☐ Submerged pile/pile cap/footing ☐ Other:
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)*	1. Cable-supported bridge ☒ Tower ☐ Main/secondary cable ☐ Cable anchorage ☐ Anchor rod ☐ Damping system ☐ Strand shoes ☐ Cable bands ☐ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:
	Other:	

Monitoring Interest

☐ Crack/fracture ☐ Expansion/contraction ☐ Rotation/torsion ☐ Wear/spalling/scaling/delamination
☐ Section loss ☐ Settlement ☐ Misalignment ☐ Connection failure or deficiencies
☐ Deformation ☐ Wire breakage ☐ Mechanical/electrical malfunction ☐ Impact damage
☐ Debonding ☐ Erosion/scour ☐ Looseness and pounding ☐ Excessive joint closing/opening
☒ Corrosion ☐ Environmental ☐ Other:

Measurement Metric

☐ Strain ☐ Deflection/displacement ☐ Acceleration/vibration ☐ Moisture/humidity level
☐ Temperature ☐ Magnetic field/flux ☒ Electrical voltage/current ☐ Chemical composition
☐ Radar waves ☐ Acoustic waves ☐ Magnetic waves ☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☐ Wind speed/direction ☐ Other:

3. Cost		
Hardware	Sensor	Expected to cost less than $20 per sensor.
	Data acquisition system	
	Communication system	
	Data archiving system	
	Other	
Software		
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	Designed to last for 50 years
Power	
Environmental conditions	
Data storage/transfer/ processing	
Other:	

5. Implementation Needs	
Power source	
Accessibility	
Technical expertise	
Other:	

6. Availability

APL is in the process of licensing the technology to companies for their manufacture, and it is expected to have this technology licensed and available to the general market in mid 2005.

7. On-Going or Completed Bridge Related Projects and References

Researchers have installed several prototype Smart Aggregates in a bridge deck in Montgomery County, Maryland, and are gathering performance data.

References:

- Cain, R.P., Carkhuff, B.G., Drinivasan, R., Grossman, K.R., and Weiskopf, F. "Packaging for a Sensor Platform Embedded in Concrete," Proceedings of Material Research Society Symposium, Vol. 682E, San Francisco, Californi, April 17-20, 2001.
- "Embedded Miniature Sensors Detect Chloride in Bridge Decks, Civil Engineering," June 2003 pp. 42-43.

8. Notes

- Prototype Smart Aggregates have been manufactured and are undergoing reliability measurements.
- Two types of different versions of Smart Aggregates are being developed: sensors (i) measuring the concentration of chloride ions and (ii) measuring the actual corrosion rate using a sacrificial sensor; the new device under development uses the alternating current impedance technique to determine the corrosion rate of a metal sample within the sensor.

1. General Information

Description of Technology	Fatigue Detecting Sensor (FDS): for detecting oncoming fatigue cracks; can be used for remaining life evaluation of steel structures.		
Manufacturer and Contact information	Kawasaki Heavy Industries (KHI), Inc. (US office) 599 Lexington Avenue, Suite 3901, New York, New York 10022	www.khi.co.jp/index_e.html Tel: (212) 759-4950 Fax: (212) 759-6421	
Features	Sensor type	FDS (made of two metal foils or leaves): lengh of fatigue crack growth is converted into structural fatigue damage based on the crack growth characteristics of thin metal.	
	Data acquisition, processing, and archiving		
	Communications		
	'Smart' attributes		
	Other	The upper leaf is a sensing foil made of nickel and the lower leaf is a base foil made of 36% Ni-Fe invar alloy. The two foils are bonded at their far ends; size of FDS is from 9 x 7 x 0.07 to 34 x 22 x 0.45 mm.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☐ Timber:	☐ Plank	☐ Nailed laminated	☐ Glue-laminated	☐ Prestressed laminated	☐ Stressed timber
		☐ Other:				
	☐ Concrete:	☐ Reinforced	☐ Prestressed/post-tensioned			
		☐ Other:				
	☒ Steel:	☐ Grid	☒ Orthotropic	☒ Buckle plate	☐ Corrugated steel flooring	
		☐ Other:				
	☐ FRP:					
Superstructure	*Primary Element*					
	☒ Multi-beam/girder system:	☒ Girder floor beam/diaphragm system	☐ Tee beam	☐ Box girder	☐ Channel beam	
	☐ Slab					
	☒ Truss member					
	☒ Arch element					
	☐ Other:					
	Secondary Element					
	☒ Connector and fastener:	☐ Riveted/bolted	☒ Welded	☐ Pin & hanger	☐ Splice	
	☒ Bracing:	☒ Cross	☒ Lateral	☒ Sway		
	☒ Diaphragm					
	☒ Cover plate					
	☒ Stiffener					
	☐ Other:					
	Bearing					
	☒ Fixed					
	☒ Expansion:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	☐ Other:					
	Other:					
Substructure	☐ Abutment:	☐ Footing	☐ Bridge seat	☐ Piles	☐ Wall (stem/back/wing)	
		☐ Other:				
	☐ Pier/bent/extended pile:	☐ Pier cap	☐ Shaft	☐ Column/stem	☐ Submerged pile/pile cap/footing	
		☐ Other:				
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)*					
	1. Cable-supported bridge					
	☒ Tower	☒ Main/secondary cable	☒ Cable anchorage	☒ Anchor rod	☒ Damping system	
	☒ Strand shoes	☒ Cable bands	☒ Cable enclosures	☐ Other:		
	2. Movable bridge					
	☐ Electric brakes	☐ Motors and power	☐ Operating machinery and equipment	☐ Other:		
	Other:					

Monitoring Interest

☒ Crack/fracture	☐ Expansion/contraction	☐ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☐ Section loss	☐ Settlement	☐ Misalignment	☐ Connection failure or deficiencies
☐ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☐ Impact damage
☐ Debonding	☐ Erosion/scour	☐ Looseness and pounding	☐ Excessive joint closing/opening
☐ Corrosion	☐ Environmental	☐ Other:	

Measurement Metric

☐ Strain	☐ Deflection/displacement	☐ Acceleration/vibration	☐ Moisture/humidity level
☐ Temperature	☐ Magnetic field/flux	☐ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☒ Other: Crack growth characteristics.	

3. Cost		
Hardware	Sensor	
	Data acquisition system	
	Communication system	
	Data archiving system	
	Other	
Software		
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	
Power	
Environmental conditions	
Data storage/transfer/ processing	
Other: Minimum detectable stress range for seel application is $\Delta\sigma$ = 20MPa, which measures $\Delta\varepsilon = 95 \times 10^{-6}$.	

5. Implementation Needs	
Power source	
Accessibility	
Technical expertise	
Other:	

6. Availability

Upon agreement.

7. On-Going or Completed Bridge Related Projects and References

References:

- Muragishi, O., Nihei, K., and Kobayashi, T. 2003: "Remaining Life Evaluation by Fatigue Detecting Sensor," The first International Conference on Structural Health Monitoring and Intelligent Infrastructure, Tokyo, Japan, 2003.
- Kawaguchi, Y., Ohgaki, K., Kobayashi, T., Kawajiri, K., and Imashioya, M. 2003: "Comparison of Remaining Life Evaluations by Fatigue Detecting Sensor and Stress Frequency Method, 58th Annual Meeting, Japan Soc. C.E.

8. Notes

- For over 100 years, KHI has manufactured and provided various sensors for various applications.
- FDS is very small and can be applied to local stress concentrated locations; it can sense the geometrically concentrated stress in the vicinity of welding beads or other weld locations; responds even to compressive cyclic stresses.
- FDS is easy to attached with commercial adhesive; requires no costly measuring instrument nor wiring.
- According to KHI, the current fatigue damage evaluation technology can diagnose the remaining life of a structure; FDS can be used on both new and existing bridges.
- In 2002, more than 700 pieces of FDSs were used and tested for various structures.
- In a highway bridge, the remaining life evaluation by FDS was verified by comparison with the stress frequency method (Kawaguchi et al. 2003).

1. General Information

Description of Technology	Real-time, on-line continuous monitoring of structural integrity.	
Manufacturer and Contact information	Kinemetrics, Inc. 222 Vista Avenue, Pasadena, CA 91107	www.kinemetrics.com Tel: (626) 795-2220 Fax: (626) 795-0868
Features	Sensor type	Accelerometers, displacement transducers, strain gages, anemometers and others (temperature, etc.).
	Data acquisition, processing, and archiving	Mt. Whitney (a full-featured multi-channel central recording system, remote data acquisition with real time digital data output). PC with OASIS software (data processing and alerting system).
	Communications	Two fiber optic cables to link the data acquistion system and the data processing system. Various other communication options are available upon request (Internet/Ethernet, Satellite, etc.).
	'Smart' attributes	Real-time, continuous monitoring with autonomous alarm system; exceedance of pre-established levels will result in autonomous audible and/or visual alarms requiring response from the structure managers.
	Other	Remote control and display of system functions through direct feedback. Visual display of subject structure including sensor icons. GPS system optional.

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☒ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☒ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☒ Main/secondary cable ☒ Cable anchorage ☒ Anchor rod ☒ Damping system ☒ Strand shoes ☒ Cable bands ☒ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☒ Crack/fracture	☐ Expansion/contraction	☒ Rotation/torsion	☒ Wear/spalling/scaling/delamination
☐ Section loss	☒ Settlement	☒ Misalignment	☒ Connection failure or deficiencies
☒ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☒ Impact damage
☐ Debonding	☐ Erosion/scour	☐ Looseness and pounding	☒ Excessive joint closing/opening
☐ Corrosion	☒ Environmental	☒ Other: Seismic activity.	

Measurement Metric

☒ Strain	☒ Deflection/displacement	☒ Acceleration/vibration	☒ Moisture/humidity level
☒ Temperature	☐ Magnetic field/flux	☒ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☒ Wind speed/direction	☐ Other:	

3. Cost		
Hardware	Sensor	Strain gages: $1,000 per unit. Displacement transducers: $1,000 per unit. Anemometers: $1,000 per unit. Accelerometer: $1,200 per unit (uniaxial); $3,300 per unit (triaxial). Many other sensors available.
	Data acquisition system	Mt. Whitney: $25,000
	Communication system	
	Data archiving system	
	Other	
Software	OASIS: ±$25,000.	
Labor	Installation	
	Use	
Other: All prices are subjected to vary depending on specification, capability, and other requirements; additional costs are added for advanced technology (e.g., GPS system, wireless communication system, solar-powered system, etc.).		

4. Limitations	
Life expectancy	No official life expectancy.
Power	12V DC. 110/220V AC. Batteries: two batteries Model LCL12V38P (Panasonic).
Environmental conditions	-20°C to 70°C, 0 to100% relative humidity.
Data storage/transfer/ processing	Depends on type of system used.
Other:	

5. Implementation Needs	
Power source	Battery, AD/DC, solar panel.
Accessibility	Direct access needed for sensor installation. Remote data acquisition, control and management.
Technical expertise	Engineering background. Moderate training on how to use the system. Engineers are available for assistance.
Other:	

6. Availability

2 to 5 weeks for standard products (longer time for custom design).
Services and consulting: upon agreement.

7. On-Going or Completed Bridge Related Projects and References

RAMA IX Bridge, Bangkok, 2000.
Namphe Bridge, Korea, 1996.
Campestre Bridge, Mexico City
Halkis Bridge, Greece, 1994.
Golden Gate Bridge, Okland Bay Bridge, Vincent Thomas Bridge, California.
Marga-Marga Bridge, Chile.
Many other bridge monitoring projects in many countries.

References:

• Nigbor, R.L., Diehl, J.G. "Two Year's Experience Using OASIS Real-time Remote Condition Monitoring System on Two Large Bridges," Structural Health Monitoring, Current Status and Perspectives, Stanford University, Palo Alto, California, pp. 555-563, 1997.
• Some case studies and references are available on company website.

8. Notes

• Founded in 1969, Kinemetrics has developed, manufactured and provided instruments and services for various applications including bridge monitoring.
• Kinemetrics offers a complete monitoring and consulting service; offers environmental (Aspen) and seismic monitoring (Sierra) system; the company has specialties in seismic monitoring.
• System monitoring software is capable of: visual display of subject structure including sensor icons; real-time, dual-level alerting of damage states including location; sensor icon, click-on waveform display and statistics from any channel; remote command/control of acquisition system; expandable to multiple bridges/systems using networking methodologies.
• In general, the company designs and builds a monitoring system based on client's specifications and requirements.

1. General Information

Description of Technology	Vibration test system and data acquisition system, and othere measurement instruments.	
Manufacturer and Contact information	LDS Test and Measurement LLC. 8551 Research Way, m/s 140, Middleton, Wisconsin 53562	www.lds-group.com Tel: (608) 821-6651 Fax: (608) 821-6691
Features	Sensor type	
	Data acquisition, processing, and archiving	Liberty: rugged, low-power modular data acquisition system with sample rates up to 100 kS/s per channel; 4-slot enclosure accommodates from 4 to 64 channels internally and 8-slot mainframe houses up to 128 channels. General purpose and Bridge/DC voltage modules (see Note for detail). Perception Standard Software: PC software for control, monitoring data transfer, analysis and export.
	Communications	Liberty mainframe communicates with Windows computers via 100Mb/s Ethernet. Optional wireless communication available upon request.
	'Smart' attributes	
	Other	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☒ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☒ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☒ Main/secondary cable ☒ Cable anchorage ☒ Anchor rod ☒ Damping system ☒ Strand shoes ☒ Cable bands ☒ Cable enclosures ☐ Other: 2. Movable bridge ☒ Electric brakes ☒ Motors and power ☒ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☐ Crack/fracture	☐ Expansion/contraction	☐ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☐ Section loss	☐ Settlement	☐ Misalignment	☐ Connection failure or deficiencies
☐ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☐ Impact damage
☐ Debonding	☐ Erosion/scour	☐ Looseness and pounding	☐ Excessive joint closing/opening
☐ Corrosion	☐ Environmental	☐ Other:	

Measurement Metric

☒ Strain	☒ Deflection/displacement	☒ Acceleration/vibration	☒ Moisture/humidity level
☒ Temperature	☐ Magnetic field/flux	☒ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☒ Wind speed/direction	☐ Other:	

3. Cost		
Hardware	Sensor	
	Data acquisition system	Liberty 4-slot Mainframe: $8,500. General purpose voltage modules: $4,250 (8-channel), $7,500 (16-channel). Bridge/DC voltage modules: $6,000 (DB37 connector), $6,500 (62-pin D connector).
	Communication system	RJ water-resistance Ethernet connector kit: $175.
	Data archiving system	
	Other	General purpose voltage modules: $4,250 (8-channel), $7,500 (16-channel). Bridge/DC voltage modules: $6,000 (DB37 connector), $6,500 (62-pin D connector).
Software	Perception Standard Software: $2,000. Perception Standard License: $1,400. Perception Advancd Software Support: $450 (for 1 year), $1,800 (for 5 years).	
Labor	Installation	
	Use	
Other: Liberty Options and Modules: Industrial grade compact flash ($190 for 128MB and $1,290 for 1GB), AC/DC converter ($195), Battery module ($1,500), Hardsided carrying case: $895.		

4. Limitations	
Life expectancy	No official life expectancy.
Power	9 to 34V DC (42V optional) or 90 to 265V AC via adapter. 66W-hour Lithium Ion internal battery.
Environmental conditions	-20 to 65°C.
Data storage/transfer/ processing	Memory: 512 MB RAM, 2 compact flash slots, R cards are available currently to 2GB each. Sample rates: 1 to 500 S/s.
Other:	

5. Implementation Needs	
Power source	Battery, AC/DC.
Accessibility	Remote data acquisition and control system.
Technical expertise	Engineering background. LDS offers training courses.
Other: Perception Standard Software requires Microsoft Windows 2000, XP or greater.	

6. Availability

4 to 6 weeks.

7. On-Going or Completed Bridge Related Projects and References

Information not available.

8. Notes

- LDS is a member of the SPX Corporation, a $5.2 billion global provider of technical products and systems, industrial products, services and service solutions; SPX has operations in 19 countries with the worldwide headquarters located in the United States at Charlotte, North Carolina.
- A single Liberty mainframe can record 128 channels at 5 kS/s each for over 30 minutes to a single Compact Flash Card.
- General purpose Voltage Modules: each module contains a 100kS/s, 16-bit digitizer on each channel with 100mV-40V full-scale ranges, 6-pole Butterworth 20kHz anti-alias filter, and selectable Bessel or steep-slop FIR digital filter. Available in an 8 or 16 channel configuration.
- Bridge/DC Voltage Modules: each module contains a 16-bit digitizer on each channel with 2mV-10V full-scale ranges, 6-pole Butterworth 20kHz anti-alias filter, and a selectable Bessel or Butterworth FIR digital filter. Integrated excitation is 0 to 10V bipolar, 30mA.

1. General Information

Description of Technology	Real-time kinematic Global Positioning System (RTK-GPS); displacement/deformation monitoring system for long span bridges with 3D millimeter-level accuracy.	
Manufacturer and Contact information	Leica Geosystems AG Kanalstrasse 21, 8152 Glattbrugg, Switzerland	www.leica-geosystems.com Tel: +41 1809 3311 or (770) 447-6361 (US) Fax: +41 1810 7937
Features	Sensor type	
	Data acquisition, processing, and archiving	MC500: 12- or 24-channel dual-frequency GPS receiver utilizing RTK techniques to provide ten independent position solutions per second with latency of 50 milliseconds to an accuracy of one centimeter. It is packaged in a rugged aluminum housing with shock mount isolators and heavy-duty lemo connectors. Leica's GPS Network software (GPS SPIDER) provides the user with monitoring control.
	Communications	Server to GPS receiver: direct serial (RS-232) or dial-up modem (landline or wireless). Other communication options (e.g., GPS receivers, satellite, etc.) available.
	'Smart' attributes	
	Other	MC500 is designed for high vibration environments and for unattended or remotely controlled operation. Compatible antenna is AT502/503/504 (choke-ring antennas placed on the reference stations).

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☒ Nailed laminated ☒ Glue-laminated ☒ Prestressed laminated ☒ Stressed timber ☐ Other:
	☒ Concrete:	☒ Reinforced ☒ Prestressed/post-tensioned ☒ Other: rover receivers normally located at expected maximum displacemet e.g., edges of deck sections at midspan or tower.
	☒ Steel:	☒ Grid ☒ Orthotropic ☒ Buckle plate ☒ Corrugated steel flooring ☐ Other:
	☒ FRP:	
Superstructure	*Primary Element*	☐ Multi-beam/girder system: ☐ Girder floor beam/diaphragm system ☐ Tee beam ☐ Box girder ☐ Channel beam ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:
	Secondary Element	☐ Connector and fastener: ☐ Riveted/bolted ☐ Welded ☐ Pin & hanger ☐ Splice ☐ Bracing: ☐ Cross ☐ Lateral ☐ Sway ☐ Diaphragm ☐ Cover plate ☐ Stiffener ☐ Other:
	Bearing	☐ Fixed ☐ Expansion: ☐ Sliding plate ☐ Roller ☐ Rocker ☐ Pin and link ☐ Elastomeric ☐ Pot ☐ Restraining ☐ Other:
	Other:	
Substructure	☐ Abutment:	☐ Footing ☐ Bridge seat ☐ Piles ☐ Wall (stem/back/wing) ☐ Other:
	☐ Pier/bent/extended pile:	☐ Pier cap ☐ Shaft ☐ Column/stem ☐ Submerged pile/pile cap/footing ☐ Other:
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)*	1. Cable-supported bridge ☒ Tower ☐ Main/secondary cable ☐ Cable anchorage ☐ Anchor rod ☐ Damping system ☐ Strand shoes ☐ Cable bands ☐ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:
	Other:	

Monitoring Interest

☐ Crack/fracture ☐ Expansion/contraction ☒ Rotation/torsion ☐ Wear/spalling/scaling/delamination
☐ Section loss ☒ Settlement ☒ Misalignment ☐ Connection failure or deficiencies
☒ Deformation ☐ Wire breakage ☐ Mechanical/electrical malfunction ☒ Impact damage
☐ Debonding ☐ Erosion/scour ☐ Looseness and pounding ☐ Excessive joint closing/opening
☐ Corrosion ☐ Environmental ☐ Other:

Measurement Metric

☐ Strain ☒ Deflection/displacement ☐ Acceleration/vibration ☐ Moisture/humidity level
☐ Temperature ☐ Magnetic field/flux ☐ Electrical voltage/current ☐ Chemical composition
☐ Radar waves ☐ Acoustic waves ☐ Magnetic waves ☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☐ Wind speed/direction ☐ Other:

3. Cost		
Hardware	Sensor	
	Data acquisition system	
	Communication system	
	Data archiving system	
	Other	
Software		
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	No official life expectancy.
Power	
Environmental conditions	
Data storage/transfer/ processing	
Other:	

5. Implementation Needs	
Power source	
Accessibility	Direct access for installation. Monitoring performed remotely (no access needed for data acquisition).
Technical expertise	Moderate training.
Other: Operating system and database for GPS SPIDER software: Windows 2000, XP or greater, Microsoft SQL/MSDE server 2000 database. Minimum hardware requirement for GPS SPIDER software: Pentium II or higher; 500MHz, 128MB RAM; 4GB hard disk; CD-ROM or DVD drive.	

6. Availability

Upon agreement.

7. On-Going or Completed Bridge Related Projects and References

- Akashi Kaikyo Bridge, Japan.
- Yang-Pu Bridge, China.
- Tsing Ma Bridge, Kap Shui Bridge, Ting Kau Bridge, Hong Kong.
- Several application cases available on company website.

References:

- Meng, X., Roberts, G., Dodson, A., Andreotti, M., Cosser, E., and Meo, M. (2004): "Development of a Prototype Remote Structural Health Monitoring System," 1st FIG International Symposium on Engineering Surveys for Construction Works and Structural Engineering, Nottingham, UK, June 28-July 1, 2004.
- Robers, G., Meng, X., Meo, M, Dodson, A., Cosser, E., Iuliano, E., and Morris, A. (2003): "A Remote Bridge Health Monitoring System Using Computational Simulation and GPS Sensor Data," Proceedings of 11th Symposium on Deformation Measurements, Santorini, Greece, 2003.

8. Notes

- Leica Group, based in Heerbrugg, Switzerland, was formed in 1990; the company has manufactured and supplied their products to various industries in more than 120 countries around the world.
- MC500 is based on Leica's ClearTrak technology providing high quality signal reception, satellite tracking, jamming resistance and multipath integration. Data storage is a factory sealed PCMCIA smart card (8, 16, or 96MB).
- The open Leica Binary 2 data format provides complete control over the system. The ASCII Open World Interface (OWI) is provided for quick and easy configuration.
- GPS SPIDER is a new, advanced software solution, with full Internet connectivity, for controlling and operating GPS reference stations and networks. Running on Microsoft® WindowsTM platforms, GPS SPIDER can control single reference stations providing GPS services for local areas as well as networks of stations supplying GPS data, RTK and DGPS services over entire regions, states or countries. GPS SPIDER controls Leica System 1200 and System 500 reference station GPS receivers. Computers are not needed at remote sites if suitable communication links connect the receivers to the GPS SPIDER server. Once started, a GPS SPIDER reference station network with GPS1200 and GPS500 receivers runs continuously and automatically supplying the full range of GPS data, RTK and DGPS services that are needed for monitoring, surveying, engineering, construction, geodesy, GIS, etc. A unique feature of GPS SPIDER is its intuitive, graphical user interface (GPS SPIDER client) that can be installed at remote locations (e.g., on notebook PC's) as well as on the GPS SPIDER server.
- MC500 is packaged in a rugged aluminum housing with shock mount isolators and heavy-duty lemo connectors.

1. General Information

Description of Technology	Fiber optic sensing monitoring system.	
Manufacturer and Contact information	Light Structures AS Hasleveien 38, NO-0571 Oslo, Norway	www.lightstructures.biz Tel: +47 2389 7133 Fax: +47 2237 1328
Features	Sensor type	SS1T, SS3T fiber optic strain sensors: sensors are individually temperature compensated.
	Data acquisition, processing, and archiving	FBG Analyzer (1-7 channels, Maximum of 32 FBGs per channel): features a high sensor capacity at relatively high sampling rates, determines the Bragg wavelength of each grating with high precision, designed to be used with a PC and comes with driver and data-acquisition software.
	Communications	Direct wire connection. Remote communication via e.g., modem, Internet, etc. available.
	'Smart' attributes	Real time, continuous monitoring system.
	Other	Sensors are surface mountable with epoxy adhesive, and are normally covered with a glass fiber reinforced polymer laminate for mechanical protection.

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☐ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☐ Cover plate ☐ Stiffener ☐ Other:	☐ Riveted/bolted ☒ Cross	☐ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☐ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☐ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☐ Main/secondary cable ☐ Cable anchorage ☐ Anchor rod ☐ Damping system ☐ Strand shoes ☐ Cable bands ☐ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☒ Crack/fracture	☐ Expansion/contraction	☐ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☐ Section loss	☐ Settlement	☐ Misalignment	☐ Connection failure or deficiencies
☒ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☒ Impact damage
☐ Debonding	☐ Erosion/scour	☐ Looseness and pounding	☐ Excessive joint closing/opening
☐ Corrosion	☐ Environmental	☐ Other:	

Measurement Metric

☒ Strain	☐ Deflection/displacement	☐ Acceleration/vibration	☐ Moisture/humidity level
☐ Temperature	☐ Magnetic field/flux	☐ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☐ Other:	

3. Cost		
Hardware	Sensor	SS1T FBG sensor: $1,136 per unit. SS3T FBG sensor: $1,564 per unit.
	Data acquisition system	FBG Anayzer: $23,860 per unit.
	Communication system	
	Data archiving system	
	Other	Industrial PC with data processing software: $4,950.
Software	Acquisition software included with the system. Data processing software: $1300/license.	
Labor	Installation	
	Use	
Other: 19" cable termination shelf: $700. Fiber optic cable: $3 per meter.		

4. Limitations	
Life expectancy	No official life expectancy.
Power	FBG Analyzer: 220-230V AC. 110V AC optional.
Environmental conditions	SS1T and SS3T sensors: -25°C to 70°C. FBG Analyzer: 5°C to 55°C without air-conditioning.
Data storage/transfer/ processing	Any Notebook or desktop PC with Pentium processor.
Other:	

5. Implementation Needs	
Power source	AC.
Accessibility	Direct access needed for sensor installation and data acquisition (remote data acquisition optional).
Technical expertise	Basic electronic skills and knowledge of dynamics. Technicians are available for assistance.
Other:	

6. Availability

8 to 10 weeks.
Warranty valid for 12 months from system acceptance test (system start-up), covering work and components needed for repair.

7. On-Going or Completed Bridge Related Projects and References

Information not available.

8. Notes

- Light Structures AS is a recently organized company; develops, manufactures, and supplies fiber optic strain monitoring systems.
- The company offers assistance with sensor system layout and multiplexing design, as well as installation and start-up.
- Features of SS1T, SS3T fiber optic strain sensor include: 2-100 m typical lead length, longer lengths available upon request; sensor packaged for uniaxial strain and temperature; the sensor package has two pigtails and can be addressed in transmission or reflection; also available in rosette configuration for multiaxial plane strain; immunity toward electromagnetic interference; does not contribute to the total surrounding electromagnetic field.

1. General Information

Description of Technology	Osterberg-Cell (O-Cell): Bi-directional deep foundation load testing; testing in difficult locations; improved safety at the job site since there are no loads, load beams, jacks or spherical seatings overhead or above ground.	
Manufacturer and Contact information	LOADTEST, Inc. 2631 NW 41st Street, Building D, Gainesville, FL 32606	www.loadtest.com Tel: (800) 368-1138 or (352)-378-3717 Fax: (352)-378-3934
Features	Sensor type	O-Cell. O-cells® range in load capacities from 150 kips (0.7MN) to 6,000 kips (27 MN). Displacement transcuders, safety gauges, and other sensors can be used for specific purpose.
	Data acquisition, processing, and archiving	Controller and data logger. Site monitor and PC. Data processing and display by automatic data acquisition and real time plotting.
	Communications	Direct wire connect and wireless communication (e.g. telephone, cellphone, pagers, etc.).
	'Smart' attributes	Simultaneous and automatic separation of both end bearing and side shear resistance.
	Other	By using multiple O-cells® on one plane, the test capacity can be increased to more than 50,000 kips (220 MN). Additionally, multiple O-cells® on different planes can isolate distinct elements within a shaft or pile.

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☒ Other: Piles and foundation for any type of bridge

Bridge Component

Deck	☐ Timber: ☐ Plank ☐ Nailed laminated ☐ Glue-laminated ☐ Prestressed laminated ☐ Stressed timber ☐ Other:	
	☐ Concrete: ☐ Reinforced ☐ Prestressed/post-tensioned ☐ Other:	
	☐ Steel: ☐ Grid ☐ Orthotropic ☐ Buckle plate ☐ Corrugated steel flooring ☐ Other:	
	☐ FRP:	
Superstructure	*Primary Element* ☐ Multi-beam/girder system: ☐ Girder floor beam/diaphragm system ☐ Tee beam ☐ Box girder ☐ Channel beam ☐ Slab ☐ Truss member ☐ Arch element ☐ Other:	
	Secondary Element ☐ Connector and fastener: ☐ Riveted/bolted ☐ Welded ☐ Pin & hanger ☐ Splice ☐ Bracing: ☐ Cross ☐ Lateral ☐ Sway ☐ Diaphragm ☐ Cover plate ☐ Stiffener ☐ Other:	
	Bearing ☐ Fixed ☐ Expansion: ☐ Sliding plate ☐ Roller ☐ Rocker ☐ Pin and link ☐ Elastomeric ☐ Pot ☐ Restraining ☐ Other:	
	Other:	
Substructure	☒ Abutment: ☒ Footing ☐ Bridge seat ☒ Piles ☐ Wall (stem/back/wing) ☒ Other: Slurry Walls/Barrettes.	
	☒ Pier/bent/extended pile: ☐ Pier cap ☒ Shaft ☐ Column/stem ☒ Submerged pile/pile cap/footing ☒ Other: Bored piles and caissons.	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☐ Tower ☐ Main/secondary cable ☐ Cable anchorage ☐ Anchor rod ☐ Damping system ☐ Strand shoes ☐ Cable bands ☐ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:	
	Other:	

Monitoring Interest

☐ Crack/fracture ☐ Expansion/contraction ☐ Rotation/torsion ☐ Wear/spalling/scaling/delamination
☐ Section loss ☐ Settlement ☐ Misalignment ☐ Connection failure or deficiencies
☐ Deformation ☐ Wire breakage ☐ Mechanical/electrical malfunction ☐ Impact damage
☐ Debonding ☐ Erosion/scour ☐ Looseness and pounding ☐ Excessive joint closing/opening
☐ Corrosion ☐ Environmental ☒ Other: Substructure element capacity.

Measurement Metric

☒ Strain ☒ Deflection/displacement ☐ Acceleration/vibration ☐ Moisture/humidity level
☐ Temperature ☐ Magnetic field/flux ☐ Electrical voltage/current ☐ Chemical composition
☐ Radar waves ☐ Acoustic waves ☐ Magnetic waves ☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☐ Wind speed/direction ☒ Other: External load.

3. Cost		
Hardware	Sensor	
	Data acquisition system	
	Communication system	
	Data archiving system	
	Other	
Software		
Labor	Installation	
	Use	
Other: Cost is determined based on the scale and requirement of each project.		

4. Limitations	
Life expectancy	
Power	
Environmental conditions	
Data storage/transfer/ processing	
Other:	

5. Implementation Needs	
Power source	
Accessibility	
Technical expertise	
Other:	

6. Availability

Upon agreement.

7. On-Going or Completed Bridge Related Projects and References

Hana highway Bridge and Uaoa Stream Bridge, Hawaii.
3rd Crossing Bridge, Abu Dhabi
Crescent Bridges, The Palm, Dubai
Sutong Bridge and Hangzhou Bridge, Shanghai, China.
Po River Bridge, Italy.
Cooper River Bridge, Charleston, SC.
Benicia Bridge, CA
Many other projects in many countries.

References;

- Osterberg, J. "Geotechnical Engineers, Wake Up: The Soil Exploration Process Needs Drastic Change," the ADSC GeoSupport 2004 Conference: Innovation and Cooperation in the Geo-Industry, Orlando, Florida, January 29-31, 2004.
- Waxse, J.A., Osterberg, J., and Qudus, Q. "Drilled Shaft Value Engineering Delivers Success To Wahoo, Nebraska Bridge," the ADSC GeoSupport 2004 Conference: Innovation and Cooperation in the Geo-Industry, Orlando, Florida, January 29-31, 2004.
- Numerous references are available on company website.

8. Notes

- Founded in 1991, LOADTEST specializes in bi-directional deep foundation load testing using the award-winning Osterberg Cell.
- LOADTEST provides the design of testing program and complete technical assistance: preparation of specifications, O-cell™ selection and placement details, instrumentation and data acquisition, field installation, load testing, and report preparation.
- Test capacity ranges from 150 kips (0.7 MN) to greater than 50,000 kips (220 MN) under suitable conditions.
- The company has tested foundation elements over 9 ft (2.7m) diameter and 350 ft (107m) deep.
- Drilled shafts/piles have been constructed and tested with the pile head over 150 ft (46m) below ground level.
- A static test can be adapted to virtually any engineer's specification, including cyclic loading, special intervals of constant loading and time effects such as creep and setup behaviour.

1. General Information

Description of Technology	Fiber optic sensor technologies.		
Manufacturer and Contact information	Luna Innovations. 2851 Commerce St. Blacksburg, VA 24060	www.lunainnovations.com Tel: (540) 552-5128 Fax: (540) 951-0760	
Features	Sensor type	Extrinsic Fabry-Perot Interferometer (EFPI) fiber optic sensor (strain sensor, temperature sensor).	
	Data acquisition, processing, and archiving	Fiberpro 2.0 (user friendly interface, sensor integrity checking, small, desktop footprint). Fiberscan 2000 (multi-platform sensors, self-referencing, stand-alone, desktop unit).	
	Communications	Direct wire connection or other communication system upon request (e.g.,Internet, LAN network, etc.).	
	'Smart' attributes	Real-time, continuous monitoring system with remote operation.	
	Other	MUX8 Channel expansion unit (multiplexer): allows operation up to eight fiber optic sensors with Fiberscan 2000 or FiberPro 2.0. Electric and optical interface cables included.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☒ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☒ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☒ Main/secondary cable ☒ Cable anchorage ☒ Anchor rod ☒ Damping system ☒ Strand shoes ☒ Cable bands ☒ Cable enclosures ☐ Other: 2. Movable bridge ☒ Electric brakes ☒ Motors and power ☒ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☐ Crack/fracture ☐ Expansion/contraction ☐ Rotation/torsion ☐ Wear/spalling/scaling/delamination
☐ Section loss ☐ Settlement ☐ Misalignment ☐ Connection failure or deficiencies
☐ Deformation ☐ Wire breakage ☐ Mechanical/electrical malfunction ☐ Impact damage
☐ Debonding ☐ Erosion/scour ☐ Looseness and pounding ☐ Excessive joint closing/opening
☐ Corrosion ☐ Environmental ☐ Other:

Measurement Metric

☒ Strain ☒ Deflection/displacement ☒ Acceleration/vibration ☐ Moisture/humidity level
☒ Temperature ☐ Magnetic field/flux ☐ Electrical voltage/current ☒ Chemical composition
☐ Radar waves ☐ Acoustic waves ☐ Magnetic waves ☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☐ Wind speed/direction ☒ Other: Pressure.

3. Cost		
Hardware	Sensor	Fiber optic temperature sensors (embeddable or surface mountable): ~$400 per unit. Fiber optic strain sensors (embeddable or surface mountable): ~$300 per unit.
	Data acquisition system	FiberPro USB 2.0: $11,300 per unit. Fiberscan 2000: $9,800 per unit.
	Communication system	
	Data archiving system	
	Other	MUX8: $9,995 per unit.
Software	Included with the system.	
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	No official life expectancy.
Power	100/240V AC, 50/60 Hz.
Environmental conditions	0 to 40°C without air-conditioning.
Data storage/transfer/ processing	
Other:	

5. Implementation Needs	
Power source	AC.
Accessibility	Direct access needed for sensor installation and data acquisition (remote monitoring optional).
Technical expertise	Basic electronic skills and knowledge of dynamics.
Other:	

6. Availability

Sensors: 2 weeks.
Fiberscan 2000, FiberPro 2.0, MUX8: 3 weeks.

7. On-Going or Completed Bridge Related Projects and References

Information not available.

8. Notes

- Originally founded as Fiber & Sensor Technologies in 1990 (changes its name to Luna Innovations in 1998), the company has developed and manufactures various sensing and advanced material-based products.
- Luna Innovation offers consulting services to address difficult NDE/NDT or to develop unique quality assurance procedures. Customized design also available.

1. General Information

Description of Technology	Fiber optic sensor technology.	
Manufacturer and Contact information	LxSix Photonics, Inc. 520 McCaffrey, St-Laurent, Quebec, Canada H4T 1N1	www.lxsix.com Tel: (514) 599-5714 Fax: (514) 599-5729
Features – Sensor type	Fiber Bragg Grating (FBG) sensors: immunte to EMI/RFI; self calibrating; no need for reference sensor; low insertion loss; peak reflectivity: >90%; FBG sensors are either embeddable or surface mountable.	
Features – Data acquisition, processing, and archiving	Interrogator is under development.	
Features – Communications		
Features – 'Smart' attributes		
Features – Other	A Bragg-based array can be made into a lightweight and rugged device small enough to be attached to composite structures and to provide real-time and distributed monitoring.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber: ☒ Plank ☐ Other: ☒ Nailed laminated ☒ Glue-laminated ☒ Prestressed laminated ☒ Stressed timber	
	☒ Concrete: ☒ Reinforced ☐ Other: ☒ Prestressed/post-tensioned	
	☒ Steel: ☒ Grid ☐ Other: ☒ Orthotropic ☒ Buckle plate ☒ Corrugated steel flooring	
	☒ FRP:	
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Girder floor beam/diaphragm system ☒ Tee beam ☒ Box girder ☒ Channel beam ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	
	Secondary Element ☒ Connector and fastener: ☒ Riveted/bolted ☒ Welded ☒ Pin & hanger ☒ Splice ☒ Bracing: ☒ Cross ☒ Lateral ☒ Sway ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	
	Bearing ☒ Fixed ☒ Expansion: ☒ Sliding plate ☒ Roller ☒ Rocker ☒ Pin and link ☒ Elastomeric ☒ Pot ☒ Restraining ☐ Other:	
	Other:	
Substructure	☒ Abutment: ☒ Footing ☐ Other: ☒ Bridge seat ☒ Piles ☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile: ☒ Pier cap ☐ Other: ☒ Shaft ☒ Column/stem ☒ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☒ Main/secondary cable ☒ Cable anchorage ☒ Anchor rod ☒ Damping system ☒ Strand shoes ☒ Cable bands ☒ Cable enclosures ☐ Other: 2. Movable bridge ☒ Electric brakes ☒ Motors and power ☒ Operating machinery and equipment ☐ Other:	
	Other:	

Monitoring Interest

☐ Crack/fracture ☐ Expansion/contraction ☐ Rotation/torsion ☐ Wear/spalling/scaling/delamination
☐ Section loss ☐ Settlement ☐ Misalignment ☐ Connection failure or deficiencies
☐ Deformation ☐ Wire breakage ☐ Mechanical/electrical malfunction ☐ Impact damage
☐ Debonding ☐ Erosion/scour ☐ Looseness and pounding ☐ Excessive joint closing/opening
☐ Corrosion ☐ Environmental ☐ Other:

Measurement Metric

☒ Strain ☐ Deflection/displacement ☐ Acceleration/vibration ☐ Moisture/humidity level
☒ Temperature ☐ Magnetic field/flux ☐ Electrical voltage/current ☐ Chemical composition
☐ Radar waves ☐ Acoustic waves ☐ Magnetic waves ☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☐ Wind speed/direction ☐ Other:

3. Cost		
Hardware	Sensor	FBG sensors (ready to use): typically around $180 per unit.
	Data acquisition system	
	Communication system	
	Data archiving system	
	Other	Sensors are priced based on capabilities and specifications.
Software		
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	No official life expectancy.
Power	
Environmental conditions	Maximum temperature range: -40 to 80°C.
Data storage/transfer/ processing	
Other: Center wavelength tolerance: ±0.2 nm Accuracy in marking sensors: 20 mm ± 5 mm Proof test: >200 kpsi.	

5. Implementation Needs	
Power source	
Accessibility	
Technical expertise	
Other:	

6. Availability

Approximately 5 weeks.

7. On-Going or Completed Bridge Related Projects and References

Information not available.

8. Notes

- LxSix is a privetely held company of new photonic processes and manufacturing technologies for optical components; the company has developed an advanced highly automated technology platform based on intellectual property licensed from Communications Research Centre Canada (CRC).
- The company offers custom designed products (fully customizable attenuation bandwidth; spliceless multi-sensor arrays, customized array configuration, etc.).

1. General Information

Description of Technology	Optical Sensor Interrogators and Analyzers.		
Manufacturer and Contact information	Micron Optics Inc. 1852 Century Place NE, Atlanta, GA 30345	www.micronoptics.com Tel: (404) 325-0005 Fax: (404) 325-4082	
Features	Sensor type	Fiber optic sensors (Micron Optic's interrogator is compatible with most commercially available optic sensors).	
	Data acquisition, processing, and archiving	Optical information from the sensors is gathered and processed by the Micron Optics instruments. Data is transferred to a central system for further processing and analysis.	
	Communications	Direct wire connection or other communication systems (e.g., Ethernet/Internet/LAN network, etc.).	
	'Smart' attributes		
	Other	Provides fast, accurate, simultaneous tracking of hundreds of sensors on multiple optical fibers.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☒ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☒ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☒ Main/secondary cable ☒ Cable anchorage ☒ Anchor rod ☒ Damping system ☒ Strand shoes ☒ Cable bands ☒ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☐ Crack/fracture	☐ Expansion/contraction	☐ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☐ Section loss	☐ Settlement	☐ Misalignment	☐ Connection failure or deficiencies
☐ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☐ Impact damage
☐ Debonding	☐ Erosion/scour	☐ Looseness and pounding	☐ Excessive joint closing/opening
☐ Corrosion	☐ Environmental	☐ Other:	

Measurement Metric

☒ Strain	☐ Deflection/displacement	☐ Acceleration/vibration	☐ Moisture/humidity level
☒ Temperature	☐ Magnetic field/flux	☐ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☐ Other:	

3. Cost		
Hardware	Sensor	$10~$1,000 per unit.
	Data acquisition system	$9,800 to $39,000 depending on specifications and requirements.
	Communication system	
	Data archiving system	<$1,000 (standard PC)
	Other	
Software	Included.	
Labor	Installation	Typically a significant expenditure for the sensor application and fiber routing.
	Use	No calibration or PM required for instrumentation
Other:		

4. Limitations	
Life expectancy	10 to 25 years.
Power	5, 12, and 24V DC, or 100/240V AC depending on system.
Environmental conditions	-20°C to 50°C with instrumentation in controlled enclosure.
Data storage/transfer/ processing	Standard PC, Ethernet, LabVIEW, Visual Basic, etc.
Other:	

5. Implementation Needs	
Power source	AC/DC.
Accessibility	Direct or remote data acquisition and control.
Technical expertise	Training on system setup; installation is the greatest challenge.
Other:	

6. Availability

Typically 2-4 weeks.

7. On-Going or Completed Bridge Related Projects and References

East 12th Street Bridge over I-235, Des Moines, Iowa.
Micron Optics' products are used by many companies, agencies, institutes, and universities throughout the world in variuos applications. Some include; Harbin Institute of Technology, China; System Planning and Analysis, USA; NTT-AT, Japan; GHT, Italy; SMARTEC, Switzerland.

8. Notes

- For over 14 years, Micron Optics has continued to provide tunable optical technologies with best-in-class optical resolution, accuracy, transmission profile, and dynamic range.
- Features of Micron Optics interrogator include; instrument can simultaneously monitor up to 512 sensors; repeatability of 0.2 PM, stability of 2 PM; standard Ethernet port provides easy data access and TCP/IP remote control; built-in, single-board computer with color display and complete front panel controls; rack mountable.

1. General Information

Description of Technology	High-speed wireless sensor networks (G-LINK, V-LINK, SG-LINK) based on MEMS technologies.		
Manufacturer and Contact information	MicroStrain, Inc. 310 Hurricane Lane, Unit 4, Williston, VT 05495	www.microstrain.com Tel: (800) 449-3878 Fax: (800) 863-4093	
Features	Sensor type	Wireless strain gages, accelerometers and temperature sensors.	
	Data acquisition, processing, and archiving	V-Link ™ Analog Input Datalogging Transceiver: designed to operate as part of a high speed wireless sensor network.. Wireless Base Station (data acquisition system and transceiver): triggers data logging, or requests previously logged data to be transmitted to the host PC for data storage/display/analysis.	
	Communications	Wireless communication system; Base Stations have USB interface standard, WiFi/cellular phone interfaces may be provided upon request. RF communication can be triggered from up to 200 ft (60 m).	
	'Smart' attributes	Wireless configuration of sampling rates & durations, wireless strain gages offset balancing, wireles strain gages shunt calibration capabilities.	
	Other	G-Link: triaxial accelerometer node. SG-Link: wireless strain gage node.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☐ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☐ Cover plate ☐ Stiffener ☐ Other:	☐ Riveted/bolted ☒ Cross	☐ Welded ☒ Lateral	☐ Pin & hanger ☒ Sway	☐ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☐ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☐ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☐ Strand shoes 2. Movable bridge ☐ Electric brakes	☐ Main/secondary cable ☐ Cable bands ☐ Motors and power	☐ Cable anchorage ☐ Cable enclosures ☐ Operating machinery and equipment	☐ Anchor rod ☐ Other:	☒ Damping system ☐ Other:	
	Other:					

Monitoring Interest

☐ Crack/fracture	☐ Expansion/contraction	☐ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☐ Section loss	☐ Settlement	☐ Misalignment	☐ Connection failure or deficiencies
☐ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☐ Impact damage
☐ Debonding	☐ Erosion/scour	☐ Looseness and pounding	☐ Excessive joint closing/opening
☐ Corrosion	☐ Environmental	☐ Other:	

Measurement Metric

☒ Strain	☒ Deflection/displacement	☒ Acceleration/vibration	☐ Moisture/humidity level
☒ Temperature	☐ Magnetic field/flux	☐ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☐ Other:	

3. Cost		
Hardware	Sensor	Approximately $695 per unit.
	Data acquisition system	
	Communication system	
	Data archiving system	
	Other	$2,395 per a typical project; includes two V-LINK wireless strain sensing nodes, one Base Station, and software for PC based data acquisition.
Software	Included.	
Labor	Installation	Variable, 2 hours typical.
	Use	
Other: Added cost of $295 per wireless node to harden for outdoor use with NEMA 4X enclosures.		

4. Limitations	
Life expectancy	5 to 10 years.
Power	Primary batteries. 3.6 Volt lithium ion AA size internal battery recommended.
Environmental conditions	-40°C to 85°C.
Data storage/transfer/ processing	Standard Window based PC.
Other:	

5. Implementation Needs	
Power source	Battery.
Accessibility	Romote data acquisition and control.
Technical expertise	None required for installation.
Other: System requirements for Base Station: Windows 95/98/2000/XP or newer version for wireless link data acquisition software; 10 Mbytes of available hard drive space; one available serial port (RS232) or USB port.	

6. Availability

1 to 3 weeks (shipped right away if available in stock).

7. On-Going or Completed Bridge Related Projects and References

Monitoring of seven highway bridges, Vermont.
Ben Franklin Bridge, Philadelphia, Pennsylvania.

References:

- Galbreath, J.H., Townsend, C.P., Mundell, S.W., Hamel, M.J., Esser, B., Huston, D., Arms, S.W. "Civil Structure Strain Monitoring with Power-Efficient, High-Speed Wireless Sensor Networks," International Workshop for Structural Health Monitoring, Stanford, California, September 2003.
- Arms, S.W. "A Vision for Future Wireless Sensing Systems," Presentation, MicroStrain, Inc.
- Numerous technical papers and references are available on company website.

8. Notes

- Founded in 1987, MicroStrain develops and produces wireless, microminiature displacement, orientation, and force sensors.
- Wireless strain sensing node can operate with up to four distinct strain gauges.
- V-LINK has three analog voltage inputs and an on-board temperature sensor.
- Also available is Microminiature Differential Variable Reluctance Transducer (DVRT) or 'half bridge LVDT': it is among the world's smallest linear displacement sensor; can be used for critical linear displacement measurements; rugged and sensitive; capable of submersion in aqueous environments.

1. General Information

Description of Technology	SHM system utilizing a "continuous acoustic emission sensor" and an embeddable local Acoustic Emission Processor (AEP).		
Manufacturer and Contact information	North Carolina A&T State University 1601 E.Market St., Greensboro, NC 27411	dor.ncat.edu Tel: (336) 334-7995 Fax: (336) 334-7086	
Features	Sensor type	Piezoelectric sensors: an array of up to 16 peizoelectric (PZT) sensor nodes connected in series or parallel; patented configuration, referred to as the continuous sensor array (CSA).	
	Data acquisition, processing, and archiving	Acoustic Emission Processor (AEP); the AEP can interface to a digital sensor bus, locally process the analog and digital signals, and connect to a data communications bus system. The basic components of a practical acoustic emission SHM system is formed by this CSA and the AEP.	
	Communications	RF transceiver, modem, cell phone, pager, wireless hub.	
	'Smart' attributes		
	Other	The combination of the continuous sensor and the embeddable AEP can potentially enable inexpensive monitoring of large and complex structures while reducing the cost, complexity, and weight of the required instrumentation.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☐ FRP:					
Superstructure	*Primary Element* ☐ Multi-beam/girder system: ☒ Slab ☐ Truss member ☐ Arch element ☐ Other:	☐ Girder floor beam/diaphragm system	☐ Tee beam	☐ Box girder	☐ Channel beam	
	Secondary Element ☐ Connector and fastener: ☐ Bracing: ☐ Diaphragm ☐ Cover plate ☐ Stiffener ☐ Other:	☐ Riveted/bolted ☐ Cross	☐ Welded ☐ Lateral	☐ Pin & hanger ☐ Sway	☐ Splice	
	Bearing ☐ Fixed ☐ Expansion: ☐ Other:	☐ Sliding plate	☐ Roller	☐ Rocker	☐ Pin and link	☐ Elastomeric ☐ Pot ☐ Restraining
	Other:					
Substructure	☐ Abutment:	☐ Footing ☐ Other:	☐ Bridge seat	☐ Piles	☐ Wall (stem/back/wing)	
	☐ Pier/bent/extended pile:	☐ Pier cap ☐ Other:	☐ Shaft	☐ Column/stem	☐ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☐ Tower ☐ Main/secondary cable ☐ Cable anchorage ☐ Anchor rod ☐ Damping system ☐ Strand shoes ☐ Cable bands ☐ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☒ Crack/fracture	☐ Expansion/contraction	☐ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☐ Section loss	☒ Settlement	☐ Misalignment	☐ Connection failure or deficiencies
☒ Deformation	☒ Wire breakage	☐ Mechanical/electrical malfunction	☒ Impact damage
☐ Debonding	☐ Erosion/scour	☐ Looseness and pounding	☐ Excessive joint closing/opening
☐ Corrosion	☐ Environmental	☐ Other:	

Measurement Metric

☐ Strain	☐ Deflection/displacement	☐ Acceleration/vibration	☐ Moisture/humidity level
☐ Temperature	☐ Magnetic field/flux	☐ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☒ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☐ Other:	

3. Cost		
Hardware	Sensor	
	Data acquisition system	
	Communication system	
	Data archiving system	
	Other	
Software		
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	
Power	
Environmental conditions	
Data storage/transfer/ processing	
Other:	

5. Implementation Needs	
Power source	
Accessibility	
Technical expertise	
Other:	

6. Availability

Two patent applications have been filed, and the University is pursuing commercial licensing opportunities through its Office of Technology Transfer and Commercialization.

7. On-Going or Completed Bridge Related Projects and References

Reference:

- Sundaresan, M.J., Kemerling, J., Schulz, M., Nkrumah, F., and Grandhi, G. "Evaluation of a scalable structural health monitoring system based on AET," 2nd European Workshop on Structural Health Monitoring, Munich, Germany, July 7-9, 2004.
- "NC A&T and Triad Semiconductor to Collaborate on Structural Health Monitoring," Triad Semiconductor, Inc. (www.triadsemi.com).

8. Notes

- The university's invention employs the use of commercially available smart sensors in a unique sensor configuration and signal processing algorithm that may provide materials monitoring performance needed to detect and remotely address any compromise in structural integrity.
- Monitoring system requires a matrix of detectors located throughout the structure; a complete monitoring system consists of multiple CSA-Sensor Bus Interface Module pairs connected to a sensor bus and related controller.
- Triad Semiconductor, Inc. (336-721-9450; www.triadsemi.com) provides "Mixed-signal" integrated circuit (IC) technology that is ideal for realizing the AEP required to process CSA.

1. General Information

Description of Technology	Sensors and data acquisition system (various sensors and electronics, instruments supplier).		
Manufacturer and Contact information	Omega Engineering, Inc. One Omega Drive, Stamford, Connecticut 06907	www.omega.com Tel: (800) 848-4286 or (203) 359-1660 Fax: (203) 359-7700	
Features	Sensor type	Linear displacement potentiometer. Thermocouple/temperature sensor. Other sensors available (e.g., strain gage, load cell, etc.).	
	Data acquisition, processing, and archiving	OM-320 and OM-420 data logging system (portable, battery powered): records up to 24 analog and/or digital channels. 13 bit analog to digital converter. Software configuration with plug-in interface modules. PCMCIA data memory modules available. Icon-based Windows software (graphically plot up to seven data channels vs. time).	
	Communications	Direct wire connection or Modem, RS232 link with other wireless options available.	
	'Smart' attributes	Real-time, continuous monitoring with optional alarm triggering system.	
	Other	OM data logging system is designed for long-term remote data collection applications. Software provides a real-time, scrolling display of data collected on a serially connected PC screen. Other various data acquisition systems available.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☒ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☐ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☐ Main/secondary cable ☒ Cable anchorage ☒ Anchor rod ☒ Damping system ☒ Strand shoes ☒ Cable bands ☒ Cable enclosures ☐ Other: 2. Movable bridge ☒ Electric brakes ☒ Motors and power ☒ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☐ Crack/fracture ☐ Expansion/contraction ☐ Rotation/torsion ☐ Wear/spalling/scaling/delamination
☐ Section loss ☐ Settlement ☐ Misalignment ☐ Connection failure or deficiencies
☐ Deformation ☐ Wire breakage ☐ Mechanical/electrical malfunction ☐ Impact damage
☐ Debonding ☐ Erosion/scour ☐ Looseness and pounding ☐ Excessive joint closing/opening
☐ Corrosion ☐ Environmental ☐ Other:

Measurement Metric

☒ Strain ☒ Deflection/displacement ☒ Acceleration/vibration ☒ Moisture/humidity level
☒ Temperature ☐ Magnetic field/flux ☒ Electrical voltage/current ☒ Chemical composition
☐ Radar waves ☐ Acoustic waves ☐ Magnetic waves ☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☐ Wind speed/direction ☒ Other: Conductivity.

3. Cost		
Hardware	Sensor	Thermocouple/temperature sensors: $20~$40 per unit. Linear displacement potentiometer: $260~$415 per unit.
	Data acquisition system	OM-320: $2,480. OM-420: $2,980. OMB-DAQ-56: $1,200.
	Communication system	
	Data archiving system	
	Other	I/O modules: $140~$380.
Software	Included.	
Labor	Installation	
	Use	
Other: Accessories:OM-320-MM-14.4: $220 (14.4 Kbaud modem). OM-320-MC-50: $120 (512K PCMCIA memory card). OM-320-MC-200: $260 (2 MB PCMCIA memory card). OM-320-MC-400: $360 (4 MB PCMCIA memory card). OM-320-PD-2: $280 (PCMCIA drive connects to IBM PC serial port or USB port for reading data from PCMCIA SRAM cards, Includes software drivers). OM-320-TSA-1: $120 (Terminal strip adapter). OM-320-FTG-1: $14 (Liquid-tight fittings). OM-320-DCXF-115/12: $14 (115 Vac power adapter). OM-320-DCXF-230/12: $25 (115/230 Vac power adapter). OM-320-CAR-4: $16 (RS-232C cable). OM-320-RJDB-25H: $28 (RJ-11 to DB25 adapter). OM-320-RJDB-9H: $28 (RJ-11 to DB9 adapter).		

4. Limitations	
Life expectancy	No official life expectancy.
Power	Power consumption: 9V DC, 7mA between readings, 50mA during readings. External power: 9 to 16V DC, 10 to 12V AC from andy semi-regulated external source.
Environmental conditions	-10 to 60°C, 90% relative humidity, non-condensing.
Data storage/transfer/ processing	Data storage: 30,000 samples internal, up to 330,000 samples with optional PCMCIA removable memory card. Data memory backup: lithium cell, 1 year @ 25°C.
Other:	

5. Implementation Needs	
Power source	Battery, AC/DC.
Accessibility	Direct access or remote wireless data acquisition.
Technical expertise	Basic electronics and computer skills. Omega provides technical supports. Handbook available.
Other:	

6. Availability
Shipped in 3 to 5 days for stock products, 1 to 4 weeks otherwise.

7. On-Going or Completed Bridge Related Projects and References
No information available.

8. Notes
• Since 1962, OMEGA has offered more than 100,000 state-of-the-art products for measurement and control of temperature, humidity, pressure, strain, force, flow, level, pH and conductivity; OMEGA also provides a complete line of data acquisition and custom engineered products.

1. General Information

Description of Technology	Various sensors and instruments for measurement, control and data acquisition.	
Manufacturer and Contact information	Omni Instruments. 120-122 King Street, Broughty Ferry, Dundee, DD5 1EW, Scotland	www.omniinstruments.co.uk Tel: +44 (0)8700 43 40 40 Fax: +44 (0)8700 43 40 45
Features	Sensor type	Displacement, accelerometer, humidity and temperature sensors, load cells, etc.
	Data acquisition, processing, and archiving	Remote data logging system (retrieve logged data and view real-time data). EV 4008 digital event logger (8-channel, event based rather than time based, up to 40,000 events can be logged and downloaded in chronological order). DataWeb 4000 logger (Ethernet network without the need for PC interface, real-time and historical data logging). OmniVeiw software (real-time chart and monitor displays, network up to 64 modules).
	Communications	Direct wire connection or other communication options (e.g., radio, modem, telephone line, Internet, etc.).
	'Smart' attributes	Real-time, continuous monitoring with alarming capacity depending on products used and the system configuration.
	Other	Also available is a radio data logging system (capable of up to 250 channels with 2-3 kilometers): the system connects sensors and process signals via radio transmitters to a central base station with a built-in data logger.

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☒ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☐ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☐ Main/secondary cable ☒ Cable anchorage ☒ Anchor rod ☒ Damping system ☒ Strand shoes ☒ Cable bands ☒ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☐ Crack/fracture	☐ Expansion/contraction	☐ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☐ Section loss	☐ Settlement	☐ Misalignment	☐ Connection failure or deficiencies
☐ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☐ Impact damage
☐ Debonding	☐ Erosion/scour	☐ Looseness and pounding	☐ Excessive joint closing/opening
☐ Corrosion	☐ Environmental	☐ Other:	

Measurement Metric

☒ Strain	☒ Deflection/displacement	☒ Acceleration/vibration	☒ Moisture/humidity level
☒ Temperature	☐ Magnetic field/flux	☐ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☐ Other:	

3. Cost		
Hardware	Sensor	$255~$2,175 per unit (£1.00=$1.82) depending on type of sensor.
	Data acquisition system	Remote data logging system: $1,629. EV4000 digital event logger: $536-$865. DataWeb 4000 logger: $2,175. Radio data logging system: $1420 (base unit) plus $319-$592 per unit (remote transmitter).
	Communication system	Some may be included in the data acquisition system.
	Data archiving system	
	Other	
Software	OmniView: $355.	
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	No official life expectancy.
Power	Remote data logging system: 5 to 32V DC, 24 A/H alkaline 6V or 12V gel cell (60 days continuous standby or 2 years at 1 hour standby). DataWeb 4000 logger: 12V DC @ 6W max. Radio data logging system: 12V DC @ 500mA (external), 6 x AA ni Mh bettery (internal) with 8 hours backup.
Environmental conditions	Remote data logging system: -40°C to 60°C operating temperature, 0 to 90% relative humidity. DataWeb 4000 logger: -5°C to 45°C (23 to 113°F) operating temperature, 0 to 90% relative humidity. Radio data logging system: -10 to 55°C operating temperature, 0 to 90% relative humidity (non-condensing).
Data storage/transfer/ processing	
Other:	

5. Implementation Needs	
Power source	Battery, AC/DC, solar panel.
Accessibility	Direct access needed for sensor installation. Remote data acquisition optional.
Technical expertise	Basic electronic and computer skills. Minimal training.
Other:	

6. Availability

1 to 6 weeks depending on type of products.

7. On-Going or Completed Bridge Related Projects and References

Many bridges in many countries; detailed information not available.

8. Notes

- Omni Instrument offers products and services from a single component to a complete system for most measurement, control, and data acquisition requirements.

1. General Information

Description of Technology	Fiber Optics Distributed Sensing Techniques.	
Manufacturer and Contact information	OMNISENS SA PSE-C, 1015 Lausanne, Switzerland	www.omnisens.com Tel: (847) 828-6808 (Chicago office) Fax: (773) 463-9584
Features	Sensor type	
	Data acquisition, processing, and archiving	DiTeSt (Fibre Optics Brillouin Analyzer): a fibre optics and laser-based monitoring system using an optical interaction measurement principle (Stimulated Brillouin Scattering); distributed measurement of strain and temperature; capable of measuring thousands of locations (points) in just one shot by means of a single optical fibre end.
	Communications	The database is accessible from remote computers through a LAN network. Other options are possible.
	'Smart' attributes	Automatic self compensation of all instrumental and environmental drift.
	Other	DiTest is capable of strain sensitivity of 20μ (0.002%); temperature sensitivity of 1°C; high spatial resolution; extended range up to 25 Km.

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☒ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☒ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☒ Main/secondary cable ☒ Cable anchorage ☒ Anchor rod ☒ Damping system ☒ Strand shoes ☒ Cable bands ☒ Cable enclosures ☐ Other: 2. Movable bridge ☒ Electric brakes ☒ Motors and power ☒ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☐ Crack/fracture ☐ Expansion/contraction ☐ Rotation/torsion ☐ Wear/spalling/scaling/delamination
☐ Section loss ☐ Settlement ☐ Misalignment ☐ Connection failure or deficiencies
☒ Deformation ☐ Wire breakage ☐ Mechanical/electrical malfunction ☐ Impact damage
☐ Debonding ☐ Erosion/scour ☐ Looseness and pounding ☐ Excessive joint closing/opening
☐ Corrosion ☐ Environmental ☐ Other:

Measurement Metric

☒ Strain ☐ Deflection/displacement ☐ Acceleration/vibration ☐ Moisture/humidity level
☒ Temperature ☐ Magnetic field/flux ☐ Electrical voltage/current ☐ Chemical composition
☐ Radar waves ☐ Acoustic waves ☐ Magnetic waves ☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☐ Wind speed/direction ☐ Other:

3. Cost		
Hardware	Sensor	
	Data acquisition system	$100,000~$140,000 per unit.
	Communication system	
	Data archiving system	
	Other	
Software		
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	No official life expectancy.
Power	115/235V AC. Power requirements of <400W.
Environmental conditions	-270°C to 500°C.
Data storage/transfer/ processing	Internal hard disc (5GB or more). 32MB flash memory stick (USB).
Other: Industrial PC with dedicated analytical software.	

5. Implementation Needs	
Power source	AC.
Accessibility	Direct access needed but the instrument can be configured for long term automatic unattended measurements. The measurements are recorded automatically and stored in a database and can easily be retrieved for further analysis.
Technical expertise	Moderate training on how to use the system.
Other:	

6. Availability
3 weeks to 3 months (upon agreement).

7. On-Going or Completed Bridge Related Projects and References
Some application notes and project information are available on websites of Omnisens and SMARTEC.

8. Notes
• Omnisens was founded in 1999 as a spin-off company of the Nanophotonics and Metrology Laboratory (NAM) of the Swiss Federal Institute of Technology in Lausanne (EPFL). • DiTest can also be purchased from SMARTEC (www.smartec.ch). • DiTeSt system is compatible with standard database and can be integrated with measurements from other sensors (e.g., SOFO, ADAM from SMARTEC).

1. General Information

Description of Technology	Data Logger / Controllers technology.		
Manufacturer and Contact information	Onset Computer Corporation 470 MacArthur Blvd, Bourne, Massachusettes 02532	www.onsetcomp.com Tel: (800) 564-4377 or (508) 759-9500 Fax: (508) 759-9100	
Features	Sensor type	Theormocouples, Wind speed/direction sensors, Soil moisture sensors, and others.	
	Data acquisition, processing, and archiving	Logger/controller engines for embedded systems: TFX-11v/11v2 data logger/controller (including 2MB flash EEPROM memory, suitable for low-power, portable applications). Handheld, battery-operated data loggers: thermocouple logger (12 bit data logger with 43k measurement memory capacity and USB interface).	
	Communications	Direct wire connection, wireless radio modem or telephone line.	
	'Smart' attributes		
	Other	HOBO Micro station: a low-cost, multi-channel data logger for site-specific microclimates. U12 4 external channel logger. HOBOware and GreenLine (softwares for U12 data logger; simple launch, readout, and plotting).	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber: ☒ Plank ☐ Other: ☒ Nailed laminated ☒ Glue-laminated ☒ Prestressed laminated ☒ Stressed timber	
	☒ Concrete: ☒ Reinforced ☐ Other: ☒ Prestressed/post-tensioned	
	☒ Steel: ☒ Grid ☐ Other: ☒ Orthotropic ☒ Buckle plate ☒ Corrugated steel flooring	
	☒ FRP:	
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Girder floor beam/diaphragm system ☒ Tee beam ☒ Box girder ☒ Channel beam ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	
	Secondary Element ☒ Connector and fastener: ☒ Riveted/bolted ☒ Welded ☒ Pin & hanger ☒ Splice ☒ Bracing: ☒ Cross ☒ Lateral ☒ Sway ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	
	Bearing ☒ Fixed ☒ Expansion: ☒ Sliding plate ☒ Roller ☒ Rocker ☒ Pin and link ☒ Elastomeric ☒ Pot ☒ Restraining ☐ Other:	
	Other:	
Substructure	☒ Abutment: ☒ Footing ☐ Other: ☒ Bridge seat ☒ Piles ☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile: ☒ Pier cap ☐ Other: ☒ Shaft ☒ Column/stem ☒ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☒ Main/secondary cable ☒ Cable anchorage ☒ Anchor rod ☒ Damping system ☒ Strand shoes ☒ Cable bands ☒ Cable enclosures ☐ Other: 2. Movable bridge ☒ Electric brakes ☒ Motors and power ☒ Operating machinery and equipment ☐ Other:	
	Other:	

Monitoring Interest

☐ Crack/fracture ☐ Expansion/contraction ☐ Rotation/torsion ☐ Wear/spalling/scaling/delamination
☐ Section loss ☐ Settlement ☐ Misalignment ☐ Connection failure or deficiencies
☐ Deformation ☐ Wire breakage ☐ Mechanical/electrical malfunction ☐ Impact damage
☐ Debonding ☐ Erosion/scour ☐ Looseness and pounding ☐ Excessive joint closing/opening
☐ Corrosion ☒ Environmental ☐ Other:

Measurement Metric

☐ Strain ☐ Deflection/displacement ☐ Acceleration/vibration ☒ Moisture/humidity level
☒ Temperature ☐ Magnetic field/flux ☒ Electrical voltage/current ☐ Chemical composition
☐ Radar waves ☐ Acoustic waves ☐ Magnetic waves ☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☒ Wind speed/direction ☐ Other:

3. Cost		
Hardware	Sensor	6ft Beaded Thermocouple with connector: $13-15 each. 12-in. Stainless-steel probe Thermocouple: $30-35 each. Wind speed/direction sensor: $395-465. Wind speed sensor: $169-199. Soil moiture smart sensor (3m cable): $128-150.
	Data acquisition system	TFX-11: $295 each. TFX-11-v2: $275 each. HOBO U12 Thermocouple logger: $101-119. U12 temperature logger: $212-249. U12 4-channel logger: $169-199. HOBO Micro Station data logger:$169-199.
	Communication system	Radio modem: $506-595. Remote modem with remote manager software: $442-520. Radio base station with remote site manager software: $293-345. Yagi antenna kit: $234-275.
	Data archiving system	
	Other	5"x3" Prototype I/O interface board: $65 each. PC serial interface cable: $9-20. ABS case for TFX-11: $35.
Software	GreenLine softwares: $50 (for Windows) - 59 (for BoxCar 4.x owners). HOBOware Software for Mac: $50-59.	
Labor	Installation	
	Use	
Other: TFX development kit (PR-11v2, Cable-PC-3.5, Cable-TFX-11, Man-TFX-11, case, batteries & TFbasic): $195. Manual for TF-11/11v2 (hardcopy): $50. Additional connectors: $35. 100 ft Thermocouple wire: $47-55. Micro Station adaptor cable: $38-45. Micro station adaptor cable: $38-45. Water-proof communication cable: $17-20 (for 2m) to $34-40 (for 17m).		

4. Limitations	
Life expectancy	20 years plus.
Power	TFX-11/11-2v: 5.5-18V DC. U12 external channel data logger: input range of 0 to 2.5V DC and output power of 2.5V at 4mA. Radio modem: 6 alkaline D cells (included); input jack for user supplied 9v DC power source (400 mA).
Environmental conditions	Operating temperature range: 0 to 70°C (for TFX-11), -40 to 85°C (for TFX-11-2v), -20 to 70°C (U12 external channel data logger). -20 to 50°C (Radio modem). Relative humidity: up to 95 %, non condensing.
Data storage/transfer/ processing	TFX-11/11-2v: Maximum sampling rate of 3200 Hz 12 bit/6400 Hz 8 bit; TFBASIC ASSEMBLY program language.
Other: TFX-11/11-2vDigital lines of 16 I/O, plus 8 input only. U12 external channel data logger: 43,000 measurements memory capacity.	

5. Implementation Needs	
Power source	Battery, DC.
Accessibility	Direct access or remote data acquisition and control.
Technical expertise	Minimal training. Technical support available on website or through phone.
Other:	

6. Availability

1 to 5 weeks.

7. On-Going or Completed Bridge Related Projects and References

Bridge 1-704 overr Christiana Creek (carrying southbound I-95), Newark, Delaware.

Reference:

• Howell, D.A., and Shenton, H.W., III. "An In-Service Bridge Monitoring System," Proceedings of the 1st International Conference on Structural Health Monitoring and Intelligent Infrastructure, Tokyo, Japan, November 13-15, 2003.

8. Notes

• Since 1981, Onset has been making low power, miniature data logger-controller engines which are used by OEMs and end-users for embedded applications.
• Onset products are used by more than 25,000 customers in a broad range of environmental research other applications.

1. General Information

Description of Technology	OSMOS system (a long-term monitoring of global structural changes through an integration of components into or onto the structure)		
Manufacturer and Contact information	OSMOS Inc. c/o GACC 218 East North Bend Way, North Bend, WA 98045	www.osmos-group.com (www.subterra.us) Tel: (425) 888-5425 Fax: (425) 888-2725	
Features	Sensor type	Optical extensometer (fiber-optic displacement sensor). Optical strand (measuring changes in shape or position). EX-Large (similar to extensometer but for longer measurement). X-Trigger (for monitoring joint movements).	
	Data acquisition, processing, and archiving	OSMOS monitoring station: it consists of a master unit (performs all the necessary network functions) and a slave unit (performs data measurement). The patented 'dashboard' displays all the required information concerning the state of the monitored structure on the computer monitor. The entire system can be configured online.	
	Communications	Optical cable, phone, fax, e-mail, telnet, http, SMTP, FTP, TCP/IP, PPP, SMS, SNMP.	
	'Smart' attributes	Real time, continuous monitoring and alarming system. Alarms can be generated via e-mail, fax, or any other user specified means when exceeding predetermined thresholds.	
	Other	Database server establishes a modem connection with measurement points and archives all raw data and configuration data accumulated. These raw data are converted into measurement data and visualized.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☒ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☒ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☐ Main/secondary cable ☒ Cable anchorage ☒ Anchor rod ☒ Damping system ☒ Strand shoes ☒ Cable bands ☒ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☒ Crack/fracture ☒ Expansion/contraction ☒ Rotation/torsion ☒ Wear/spalling/scaling/delamination
☒ Section loss ☒ Settlement ☒ Misalignment ☒ Connection failure or deficiencies
☒ Deformation ☐ Wire breakage ☐ Mechanical/electrical malfunction ☒ Impact damage
☒ Debonding ☐ Erosion/scour ☒ Looseness and pounding ☒ Excessive joint closing/opening
☐ Corrosion ☒ Environmental ☐ Other:

Measurement Metric

☒ Strain ☒ Deflection/displacement ☒ Acceleration/vibration ☒ Moisture/humidity level
☒ Temperature ☐ Magnetic field/flux ☐ Electrical voltage/current ☐ Chemical composition
☐ Radar waves ☐ Acoustic waves ☐ Magnetic waves ☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☒ Wind speed/direction ☐ Other:

3. Cost		
Hardware	Sensor	
	Data acquisition system	
	Communication system	
	Data archiving system	
	Other	
Software		
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	20 years plus.
Power	Master: 12V DC or 100 to 260V AC, 30w power consumption. Slave: 24V DV, 1.6A.
Environmental conditions	Sensors: -20°C to 60°C. OSMOS Monitoring station: -20°C to 50°C without air conditioning.
Data storage/transfer/ processing	Depends on specification.
Other:	

5. Implementation Needs	
Power source	AC/DC, solar panel.
Accessibility	Direct access needed for sensor installation. Remote data acquisition and control.
Technical expertise	Minimal training. Basic electronic skills.
Other: Microsoft Windows 95 or newer operating system.	

6. Availability

4 to 6 weeks for standard products. (upon agreement for custom design products).

7. On-Going or Completed Bridge Related Projects and References

Reuss Bridge, Switzerland.
Skovdiget Bridge, Denmark.
Viaduct of Millau Cable-stayed Bridge, Rondeau Pedestrian Bridge, France.
Takanosu Bridge, Honmoku Bridge, Yurakucho Bridge, Japan.
Kohlbrand Bridge, Herrenbrucke Bridge, Wittenberg Bridge, Mulden Bridge, Hohenzollern Bridge, Germany.
Manhattan Bridge, 3rd Avenue Bridge, New York.
Leominster Bridge, Massachussetts.
Numerous projects in many countries.

References:

• Braunstein, J., Ruchala, J., and Hodac, B. "Smart Structures: Fiber-Optic Deformation and Displacement Monitoring," 1st International Conference on Bridge Maintenance, Safety and Management, IABMAS 2002, Barcelona, Spain, July 14-17, 2002.
• Several case studies and references are available on company website.

8. Notes

• SubTerra, Inc. (www.subterra.us) is an US affiliate for the OSMOS monitoring system.
• Connecting the sensors via standard optical cables permits measurement signals to be transmitted over long distances without the need for conversion or intermediate amplification.
• A specially developed signal processing OSMOS monitoring station is used for measuring, evaluating and displaying signals from sensors. The slave registers measurement values from the sensors, while the master processes and displays signals and performs communications with peripheral devices.
• Up to four OSMOS fiber-optic sensors, four temperature sensors and four analog signal transducers can be connected to a slave.
• Up to five slaves can be connected to a master via a bus (RS 485).
• Up to four masters can be networked together, allowing a measurement and evaluation of up to 20 slaves with a total of 80 fiber-optic sensors, 80 temperature sensors, and 80 additional sensors for metrics such as pressure, humidity, wind and inclination.

1. General Information

Description of Technology	OSMOS Weigh-In-Motion System (WIMS) for Bridges.		
Manufacturer and Contact information	OSMOS Inc. c/o GACC 218 East North Bend Way, North Bend, WA 98045	www.osmos-group.com (www.subterra.us) Tel: (425) 888-5425 Fax: (425) 888-2725	
Features	Sensor type	Optical extensometer and fiber optic strains (up to 95% measurement accuracy at highway speeds); sensors are constructed of Inert materials (brace, steel, and silicone). Syncronized CCTV (match vehicle to real-time weight measurement).	
	Data acquisition, processing, and archiving	Computerized Monitoring and collection stations (OSMOS monitoring station can be set up as a real-time capture and conversion for WIMS). The patented 'dashboard' displays all the required information concerning the state of the monitored structure on the computer monitor. The entire system can be configured online.	
	Communications	An Internet-enabled PC to monitor real-time load data; easy-to-read, color-coded load information is displayed graphically with the OSMOS Dashboard application.	
	'Smart' attributes	Automatic alerts; proactive notification that overload has occurred (e.g., green is within tolerance, yellow is approaching overload, red exceeds previously determined thresholds).	
	Other	Rugged sensors (made of inert materials) can be permanetly attached to the exterior of the bridge without damage; sensors are unaffected by EMI and are safe in flammable environments.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☐ Multi-beam/girder system: ☒ Slab ☐ Truss member ☐ Arch element ☐ Other:	☐ Girder floor beam/diaphragm system	☐ Tee beam	☐ Box girder	☐ Channel beam	
	Secondary Element ☐ Connector and fastener: ☐ Bracing: ☐ Diaphragm ☐ Cover plate ☐ Stiffener ☐ Other:	☐ Riveted/bolted ☐ Cross	☐ Welded ☐ Lateral	☐ Pin & hanger ☐ Sway	☐ Splice	
	Bearing ☐ Fixed ☐ Expansion: ☐ Other:	☐ Sliding plate	☐ Roller	☐ Rocker	☐ Pin and link	☐ Elastomeric ☐ Pot ☒ Restraining
	Other:					
Substructure	☐ Abutment:	☐ Footing ☐ Other:	☐ Bridge seat	☐ Piles	☐ Wall (stem/back/wing)	
	☐ Pier/bent/extended pile:	☐ Pier cap ☐ Other:	☐ Shaft	☐ Column/stem	☐ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☐ Tower ☐ Main/secondary cable ☐ Cable anchorage ☐ Anchor rod ☐ Damping system ☐ Strand shoes ☐ Cable bands ☐ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☐ Crack/fracture	☐ Expansion/contraction	☐ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☐ Section loss	☐ Settlement	☐ Misalignment	☐ Connection failure or deficiencies
☐ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☐ Impact damage
☐ Debonding	☐ Erosion/scour	☐ Looseness and pounding	☐ Excessive joint closing/opening
☐ Corrosion	☐ Environmental	☒ Other: Weigh-in-motion of vehicles.	

Measurement Metric

☒ Strain	☒ Deflection/displacement	☐ Acceleration/vibration	☐ Moisture/humidity level
☐ Temperature	☐ Magnetic field/flux	☐ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☒ Other: Load.	

3. Cost		
Hardware	Sensor	
	Data acquisition system	
	Communication system	
	Data archiving system	
	Other	
Software		
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	20 years plus.
Power	Master: 12V DC or 100 to 260V AC, 30w power consumption. Slave: 24V DV, 1.6A.
Environmental conditions	Sensors: -20°C to 60°C. OSMOS Monitoring station: -20°C to 50°C without air conditioning.
Data storage/transfer/ processing	Depends on specification.
Other:	

5. Implementation Needs	
Power source	AC/DC, solar panel.
Accessibility	Remote monitoring and control.
Technical expertise	Minimal training. Easy view data.
Other: PC with a Pentium 166 MHz or higher processor, 64 MB RAM; Microsoft Windows 95 or newer operating system; Internet Explorer 5.0 or later; Internet access.	

6. Availability

4 to 6 weeks for standard products. (upon agreement for custom design products).

7. On-Going or Completed Bridge Related Projects and References

Reuss Bridge, Switzerland.
Skovdiget Bridge, Denmark.
Viaduct of Millau Cable-stayed Bridge, Rondeau Pedestrian Bridge, France.
Takanosu Bridge, Honmoku Bridge, Yurakucho Bridge, Japan.
Kohlbrand Bridge, Herrenbrucke Bridge, Wittenberg Bridge, Mulden Bridge, Hohenzollern Bridge, Germany.
Manhattan Bridge, 3rd Avenue Bridge, New York.
Leominster Bridge, Massachussetts.
Numerous projects in many countries.

References:

• Braunstein, J., Ruchala, J., and Hodac, B. "Smart Structures: Fiber-Optic Deformation and Displacement Monitoring," 1st International Conference on Bridge Maintenance, Safety and Management, IABMAS 2002, Barcelona, Spain, July 14-17, 2002.
• Several case studies and references are available on company website.

8. Notes

• SubTerra, Inc. (www.subterra.us) is an US affiliate for the OSMOS monitoring system.
• OSMOS WIMS can record a moving load as it passes over a bridge automatically without the need to stop or slow down. No modification is necessary to the bridge structures, and the sensors can be installed without interrupting traffic.
• A CCTV camera connected to the monitoring station captures the images of each overweight vehicle. An on-site monitoring station synchronizes the sensors and video information and uploads it to an offsite server for real-time data processing.
• The system can perform alert processes such as sending an email, dial a pager, or actuate other alarm mechanisms and systems automatically.

1. General Information

Description of Technology	Acoustic Emission (AE) monitoring system,		
Manufacturer and Contact information	Physical Acoustics Corporation (PACNDT) 195 Clarksville Road, Princeton Jct, NJ 08550	www.pacndt.com Tel: (609) 716-4000 Fax: (609) 716-0706	
Features	Sensor type	Sensor selection based on needs (Strain sensor, displacement trasducers, accelerometers, AE sensor, EM sensors).	
	Data acquisition, processing, and archiving	Local area monitor (LAM) for remote controlled condition monitoring. Several data processing softwares. A-scan (shows magnitude of defect). C-scan (shows location of defect). PAC 60 channel data acquisiton system. Remote PC computer. Fiber optic link for data transfer.	
	Communications	Direct wire connection, or other communication systems (cell/telephone line, RF, modem, Internet, etc.).	
	'Smart' attributes	Real-time, continuous processing and autonomous alarm system for emergency situdation. (auto dial to pager/web/cell). Ability to monitor entire structure or selected area.	
	Other	AE sensor hears cracks, rubing corrosion in materials and locates where it is coming from. Alarm setting in the data acquisition and software can alert people about problem.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☐ Timber:	☐ Plank ☐ Other:	☐ Nailed laminated	☐ Glue-laminated	☐ Prestressed laminated	☐ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☒ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☒ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☒ Main/secondary cable ☒ Cable anchorage ☒ Anchor rod ☒ Damping system ☒ Strand shoes ☒ Cable bands ☒ Cable enclosures ☐ Other: 2. Movable bridge ☒ Electric brakes ☒ Motors and power ☒ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☒ Crack/fracture	☐ Expansion/contraction	☐ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☐ Section loss	☐ Settlement	☐ Misalignment	☐ Connection failure or deficiencies
☐ Deformation	☒ Wire breakage	☐ Mechanical/electrical malfunction	☐ Impact damage
☐ Debonding	☐ Erosion/scour	☒ Looseness and pounding	☐ Excessive joint closing/opening
☐ Corrosion	☐ Environmental	☐ Other:	

Measurement Metric

☐ Strain	☐ Deflection/displacement	☐ Acceleration/vibration	☐ Moisture/humidity level
☐ Temperature	☐ Magnetic field/flux	☐ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☒ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☐ Other:	

3. Cost		
Hardware	Sensor	AE sensors are approximately $400 per unit.
	Data acquisition system	
	Communication system	
	Data archiving system	
	Other	
Software		
Labor	Installation	
	Use	
Other: Big variable depending on the size of project; a complete monitoring system (56 channels) for the Ben Franklin Bridge was $200,000.		

4. Limitations	
Life expectancy	Depends on type of project (one time testing or long-term monitoring). For long-term monitoring, system can be designed to ruggedized.
Power	Depends on monitoring system.
Environmental conditions	The system can be set up to incorporate any available power sources.
Data storage/transfer/ processing	Depending on monitoring purpose.
Other:	

5. Implementation Needs	
Power source	Battery, AC/DC, solar panel.
Accessibility	Direct access or remote monitoring and control.
Technical expertise	Minimal to moderate trainings depending on monitoring purpose and size of project.
Other:	

6. Availability

Standard sensors readily available. Custom design available for various monitoring purposes (upon request).
Simple hand-held testing and AE field testing system also available.

7. On-Going or Completed Bridge Related Projects and References

Woodrow Wilson Bridge, Washington DC.
Brooklyn Bridge, Manhattan Bridges, Queensborough Bridge, Williamsburg Bridge, New York City.
Dunbar Bridge, West Virginia.
Bryte Bend Bridge, Sacramento, California.
I-10 Mississippi Riber Bridge, Louisiana.
I-205 Willemette River Bridge, West Lynn Bridge, Oregon.
Texas Intercoastal Canal Bridge, Martin Luther King Memorial Bridge, Texas Intercoastal Canal Bridge, Martin Luther King Memorial Bridge, Texas.
Numerous other projects in many countries.

References:

- Clemena, G.G., Lozev, M.G., Duke, J.C., Sison, M.F. "Acoustic Emission Monitoring of Steel Bridge Members," Final Report: VTRC 97-R13, Virginia Transportation Research Council, Charlottesville, Virginia, 1997.
- Finlayson, R.D., Friesel, M., Carlos, M., Cole, P., and Lenain, J.C. "Health Monitoring of Aerospace Structures with Acoustic Emission and Acousto-Ultrasonics," NDT in the Aerospace Industry, Insight, Vol. 43, No. 3, March 2001.
- Chotard, T.J., Smith, A., Rotureau, D., Fargeot, D., and Gault, C. "Acoustic Emission Characterisation of Calcium Aluminate Cement Hydration at an Early Age," Journal of the European Ceramic Society, April 2002.

8. Notes

- Founded in 1978, PACNDT has continuing AE experience in sensor research, (from wideband to high fidelity, low cost resonant and band limited) and acoustic emission test data interpretation experience in various applications where a material is undergoing a state of change or experiencing crack initiation or propagation.
- PACNDT offers and provides products and services including: global monitoring for critical structures; local monitoring for areas identified as problematic; confirmation of success of repairs; periodic local testing for specific stressed areas; vibration monitoring for identification of modal changes, and other client's specific needs.
- The company also offers other monitoring technologies including Electromagnetic (EM), Ultrasonic, Radiography, Vibration monitoring, etc.

1. General Information

Description of Technology	Manufacturer of accelerometers and vibration sensors.	
Manufacturer and Contact information	PCB Piezotronics, Inc. 3425 Walden Ave, Depew, New York 14043	www.pcb.com Tel: (716) 684-0001 or (888) 684-0013 Fax: (716) 684-0987
Features	Sensor type	Accelerometers and vibration sensors. 393B04: seismic, miniature, ceramic shear accelerometer. 393B31: seismic, high sensitivity, ceramic shear accelerometer. 3701G3FA3G: capacitive accelerometer.
	Data acquisition, processing, and archiving	Sensors are compatible with virtually any data logger or acquisition system that accepts analog voltage input (both positive and negative swing from a zero Volts baseline).
	Communications	
	'Smart' attributes	
	Other	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☐ Connector and fastener: ☐ Bracing: ☐ Diaphragm ☐ Cover plate ☐ Stiffener ☐ Other:	☐ Riveted/bolted ☐ Cross	☐ Welded ☐ Lateral	☐ Pin & hanger ☐ Sway	☐ Splice	
	Bearing ☐ Fixed ☐ Expansion: ☐ Other:	☐ Sliding plate	☐ Roller	☐ Rocker	☐ Pin and link	☐ Elastomeric ☐ Pot ☐ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☐ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☐ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☐ Strand shoes 2. Movable bridge ☐ Electric brakes	☐ Main/secondary cable ☐ Cable bands ☐ Motors and power	☐ Cable anchorage ☐ Cable enclosures ☐ Operating machinery and equipment	☐ Anchor rod ☐ Other:	☐ Damping system ☐ Other:	
	Other:					

Monitoring Interest

☐ Crack/fracture	☐ Expansion/contraction	☐ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☐ Section loss	☐ Settlement	☐ Misalignment	☐ Connection failure or deficiencies
☐ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☐ Impact damage
☐ Debonding	☐ Erosion/scour	☐ Looseness and pounding	☐ Excessive joint closing/opening
☐ Corrosion	☐ Environmental	☐ Other:	

Measurement Metric

☐ Strain	☐ Deflection/displacement	☒ Acceleration/vibration	☐ Moisture/humidity level
☐ Temperature	☐ Magnetic field/flux	☐ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☐ Other:	

3. Cost		
Hardware	Sensor	Model 393B04: $545 per unit. Model 393B31: $845 per unit. Model 3701G3FA3G: $575 per unit.
	Data acquisition system	
	Communication system	
	Data archiving system	
	Other	
Software		
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	No official life expectancy.
Power	Excitation voltage: 18 to 30V DC (Model 393B04), 24 to 28V DC (Model 393B31), 16 to 30V DC (Model 3701G3FA3G).
Environmental conditions	Model 393B04: -18 to 80°C. Model 393B31: -18 to 65°C. Model 3701G3FA3G: -40 to 85°C.
Data storage/transfer/ processing	
Other: Measurement range: ±5g pk (Model 393B04), ±0.5g pk (Model 393B31), ±3g pk (Model 3701G3FA3G.	

5. Implementation Needs	
Power source	DC.
Accessibility	Direct access needed for sensor installation.
Technical expertise	Basic electronics skills.
Other:	

6. Availability

2 to 5 weeks.

7. On-Going or Completed Bridge Related Projects and References

Fred Hartman Bridge, Texas (to measure cable stay vibration).

8. Notes

- PCB Piezotronics, Inc. was founded in 1967 and manufactures accelerometers, force sensors, load cells, microphones, pressure transducers, pressure transmitters, strain sensors, torque sensors, vibration sensors, signal conditioners, cables, and accessories.
- PCB's sensors and instrumentations are used for test, measurement, monitoring, and feedback control requirements in industrial, R&D, military, educational, commercial, and OEM applications.

1. General Information

Description of Technology	Linear displacement sensors.	
Manufacturer and Contact information	Penny & Giles 1 Airfield Road, Christchurch, Dorset. BH23 3TH. UK	www.pennyandgiles.com Tel: +44 (0) 1202 481771 Fax: +44 (0) 1202 484846
Features	Sensor type	Linear displacement sensors (SLS320, SLS130): a wide of choice of mounting options are available; self-aligning bearings, body clamp kits and flange mounting kits; additional protective kits can be used for harsh environment.
	Data acquisition, processing, and archiving	
	Communications	
	'Smart' attributes	
	Other	Sealing to IP66 and corrosion resistant rod end bearings; Light weight; Compact with a rugged design and body diameter of 32 mm.

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber: ☒ Plank ☐ Other: ☒ Nailed laminated ☒ Glue-laminated ☒ Prestressed laminated ☒ Stressed timber	
	☒ Concrete: ☒ Reinforced ☐ Other: ☒ Prestressed/post-tensioned	
	☒ Steel: ☒ Grid ☐ Other: ☒ Orthotropic ☒ Buckle plate ☒ Corrugated steel flooring	
	☒ FRP:	
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Girder floor beam/diaphragm system ☒ Tee beam ☒ Box girder ☒ Channel beam ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	
	Secondary Element ☐ Connector and fastener: ☐ Riveted/bolted ☐ Welded ☐ Pin & hanger ☐ Splice ☒ Bracing: ☒ Cross ☒ Lateral ☒ Sway ☒ Diaphragm ☐ Cover plate ☐ Stiffener ☐ Other:	
	Bearing ☐ Fixed ☐ Expansion: ☐ Sliding plate ☐ Roller ☐ Rocker ☐ Pin and link ☐ Elastomeric ☐ Pot ☐ Restraining ☐ Other:	
	Other:	
Substructure	☐ Abutment: ☐ Footing ☐ Other: ☐ Bridge seat ☐ Piles ☐ Wall (stem/back/wing)	
	☐ Pier/bent/extended pile: ☐ Pier cap ☐ Other: ☐ Shaft ☐ Column/stem ☐ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☐ Tower ☐ Main/secondary cable ☐ Cable anchorage ☐ Anchor rod ☐ Damping system ☐ Strand shoes ☐ Cable bands ☐ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☒ Other: Resting blocks (tapered wedges)	
	Other:	

Monitoring Interest

☐ Crack/fracture ☐ Expansion/contraction ☐ Rotation/torsion ☐ Wear/spalling/scaling/delamination
☐ Section loss ☐ Settlement ☐ Misalignment ☐ Connection failure or deficiencies
☒ Deformation ☐ Wire breakage ☐ Mechanical/electrical malfunction ☐ Impact damage
☐ Debonding ☐ Erosion/scour ☐ Looseness and pounding ☐ Excessive joint closing/opening
☐ Corrosion ☐ Environmental ☐ Other:

Measurement Metric

☐ Strain ☒ Deflection/displacement ☐ Acceleration/vibration ☐ Moisture/humidity level
☐ Temperature ☐ Magnetic field/flux ☐ Electrical voltage/current ☐ Chemical composition
☐ Radar waves ☐ Acoustic waves ☐ Magnetic waves ☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☐ Wind speed/direction ☐ Other:

3. Cost		
Hardware	Sensor	SLS130 series: $195 per unit for 25 mm stroke length and $245 for 200 mm stroke length. SLS320 series: $385 per unit for 250 mm stroke length and $540 for 1,000 mm stroke length. Quantity discounts are available.
	Data acquisition system	
	Communication system	
	Data archiving system	
	Other	
Software		
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	Dither life: 200 million operations ($100x10^6$ cycles) at ±0.5mm, 60Hz. Life at 250mm per second: Typically in excess of 100 million operations ($50x10^6$ cycles) at 25mm stroke length.
Power	Applied voltage: maximum of 74V DC.
Environmental conditions	-30°C to 100°C.
Data storage/transfer/ processing	
Other:	

5. Implementation Needs	
Power source	DC.
Accessibility	Direct access needed for sensor installation.
Technical expertise	Basic instrumentation skills.
Other:	

6. Availability

Up to 1100 mm stroke - all configurations can be supplied within five days.
1150 to 1600 mm stoke - all configurations can be supplied within ten days.

7. On-Going or Completed Bridge Related Projects and References

Tower Bridge (Bacule Bridge), London, UK.

8. Notes

- Founded in 1955, Penny & Giles has manufactured and supplied wire-wound potentiometric devices and other sensors for a wide range of industries.
- With a choice of mounting options and accessories, SLS320 is suited to heavier duty applications.
- SLS320 sensors provide feedback on the position of eight resting blocks that are used to adjust the bridge's two bascules. Each of the resting blocks is filled with two sensors-one on duty and one on standby-to indicate its position. LES Engineering (UK) specified the SLS320s with compact shafts, IP66 sealing and 10m cables.

1. General Information

Description of Technology	SoundPrint Acoustic monitoring system: SoundPrint uses an array of sensors to measure the response of a structure caused by the energy released when tensioned wires fail or other event of interest occur; tendon monitoring, corrosion, fatigue crack, bolt/rivet failure detection.	
Manufacturer and Contact information	Pure Technologies, Ltd. 10015 Old Columbia Road, Suite B-215, Columbia, MD 21046	www.soundprint.com Tel: (410)-309-7050 Fax: (410)-309-7051
Features	Sensor type	Broadband accelerometers, piezoelectronic sensors, and others.
	Data acquisition, processing, and archiving	Amplification and signal filtering equipment. PC with an A/D board and proprietary data acquisition and processing software. Filtering techniques are usd to reject acoustic events caused by ambient activities (e.g., traffic or construction).
	Communications	Data is automatically transmitted from the DAQ through a local Internet connection to the Pure Technologies data processing center, where the data is analyzed and classified.
	'Smart' attributes	Autonomous alarm system with continuous, non-intrusive remote monitoring for detecting and locating failures and other defects in high-tensile steel wire, strand or cable components.
	Other	Proprietary hardware to filter ambient noise. Monitoring system is tailored for each application; SoundPrint is available in different configurations to suit specific site conditions.

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☐ Rigid Frame ☒ Suspension ☒ Cable-stayed ☐ Vertical lift
☐ Swing ☐ Bascule ☒ Other: Steel Bridges for fatigue crack detection.

Bridge Component

Deck	☐ Timber:	☐ Plank ☐ Nailed laminated ☐ Glue-laminated ☐ Prestressed laminated ☐ Stressed timber ☐ Other:
	☒ Concrete:	☒ Reinforced ☒ Prestressed/post-tensioned ☐ Other:
	☒ Steel:	☒ Grid ☒ Orthotropic ☒ Buckle plate ☒ Corrugated steel flooring ☐ Other:
	☐ FRP:	
Superstructure	*Primary Element*	☒ Multi-beam/girder system: ☒ Girder floor beam/diaphragm system ☒ Tee beam ☒ Box girder ☒ Channel beam ☒ Slab ☒ Truss member ☒ Arch element ☒ Other: Members with prestressed or post-tensioned wire or cable
	Secondary Element	☒ Connector and fastener: ☒ Riveted/bolted ☐ Welded ☐ Pin & hanger ☐ Splice ☐ Bracing: ☐ Cross ☐ Lateral ☐ Sway ☐ Diaphragm ☐ Cover plate ☐ Stiffener ☐ Other:
	Bearing	☐ Fixed ☐ Expansion: ☐ Sliding plate ☐ Roller ☐ Rocker ☐ Pin and link ☐ Elastomeric ☐ Pot ☐ Restraining ☐ Other:
	Other:	
Substructure	☐ Abutment:	☐ Footing ☐ Bridge seat ☐ Piles ☐ Wall (stem/back/wing) ☐ Other:
	☐ Pier/bent/extended pile:	☐ Pier cap ☐ Shaft ☐ Column/stem ☐ Submerged pile/pile cap/footing ☒ Other: Ground anchor.
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)*	1. Cable-supported bridge ☐ Tower ☒ Main/secondary cable ☐ Cable anchorage ☐ Anchor rod ☐ Damping system ☐ Strand shoes ☐ Cable bands ☐ Cable enclosures ☒ Other: Suspender ropes (hangers). 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:
	Other:	

Monitoring Interest

☒ Crack/fracture	☐ Expansion/contraction	☐ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☐ Section loss	☐ Settlement	☐ Misalignment	☒ Connection failure or deficiencies
☐ Deformation	☒ Wire breakage	☐ Mechanical/electrical malfunction	☒ Impact damage
☐ Debonding	☐ Erosion/scour	☒ Looseness and pounding	☐ Excessive joint closing/opening
☒ Corrosion	☐ Environmental	☐ Other:	

Measurement Metric

☐ Strain	☐ Deflection/displacement	☐ Acceleration/vibration	☐ Moisture/humidity level
☐ Temperature	☐ Magnetic field/flux	☐ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☒ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☐ Other:	

3. Cost		
Hardware	Sensor	Piezoelectric sensors: $100 per unit. Others: $30~$1,500 per unit depending on type of sensor.
	Data acquisition system	$50,000~$150,000
	Communication system	Variable.
	Data archiving system	Variable.
	Other	Data processing and archiving usually runs about 10% of the purchase and installation costs.
Software	Included.	
Labor	Installation	Variable. It can range from a few days to several months depending on size and complexity of the project.
	Use	Manpower needed to regulary review data for events of interests.
Other: Typical lightening protection: $30,000. Galvanized steel conduit (for runing data cable): $90,000 for several thousand feet. Standard maintenance items will be included in the costs for data processing.		

4. Limitations	
Life expectancy	System installed with rugged hardware, designed to last permanently with proper maintenance.
Power	Typically 110V AC. The company designs the systems to accept whatever power they can across.
Environmental conditions	System can be designed to withstand any harsh environmental condition.
Data storage/transfer/ processing	Depends on project needs and specifications.
Other:	

5. Implementation Needs	
Power source	Battery, AC/DC, solar panel.
Accessibility	Remote monitoring and control. Access to the computer needed for maintenance.
Technical expertise	Moderate training. Basic electronics and computer skills. Engineers, technician, and maintenance crew available for assistance.
Other: Computer preferably be located out of weather (at least weatherproof, climate controlled enclosure required).	

6. Availability

Upon agreement.

7. On-Going or Completed Bridge Related Projects and References

Waldo Hancock Bridge, Verona, Maine. Commissioned: August 2003.
Stay-cable fatique testing performed by University of Texas at Austin and Texas DOT. Duration: March 2001-April 2003.
Quincy Bayview Bridge, Quincy, Illinois. Commissioned: June 2002.
Fred Hartman Bridge, Harris County, Texas. Commissioned: March 2002.
Bear Mountain Bridge, Fort Montgomery, New York. Commissioned: February 2001.
Bronx-Whitestone Bridge, New York City. Commissioned: November 2000.
Many other monitoring projects in many countries.

References:

• Paulson, P., and Cullinton, D. "Evaluation of Continuous Acoustic Monitoring as a Means of Detecting Failures in Post-tensioned and Suspension Bridges," the XIII FIP Congress and Exhibition, Amsterdam, Netherlands, May 23-29, 1998.
• Several case studies and references are available on company website.

8. Notes

• Since its incorporation in 1993, SoundPrint® has provided infrastructure owners and managers with continuous, remote structural monitoring of infrastructure components and automatic surveillance of structures subject to damage.
• SoundPrint vibration monitoring system provides a continuous remote health monitoring solution for structures containing cables.
• SoundPrint high load damage surveillance system provides a documentary record of the event and facilitates positive identification of the vehicle.
• System operation status, data transfer, software upgrades, troubleshooting, and acquisition parameters can be altered from remote locations.
• Data can be accessed directly by clients using the secure client access website.
• Reports can be generated summarizing activity in a structure over a specified period.
• The SoundPrint acoustic monitoring system can be incorporated with other systems.
• Also available is wireless monitoring system (with solar panel, battery, transmitter, receiver located at data acquisition system).

1. General Information

Description of Technology	Temperature sensors and thermocouples for OEM and various applications.		
Manufacturer and Contact information	RdF Corporation 23 Elm Avenue, PO Box 490, Hudson, NH 03051	www.rdfcorp.com Tel: (800) 445-8367 or (603) 882-5195 Fax: (603) 882-6925	
Features	Sensor type	Temperature sensors and thermocouples. Model 22810: a small, flexible, low-mass ployimide insulated surface sensor designed to provide a surface temperature. Model 22391/2/3: platinum surface RTD sensor sealed for condensing or wet environments. Model 22802: heavy duty industrial surface mountable sensor.	
	Data acquisition, processing, and archiving		
	Communications		
	'Smart' attributes		
	Other	Model 22488/9: non-penetrating, low-cost wire-wound platinum surface RTD (mounted by bolt or strap).	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☒ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☒ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☒ Main/secondary cable ☒ Cable anchorage ☒ Anchor rod ☒ Damping system ☒ Strand shoes ☒ Cable bands ☒ Cable enclosures ☐ Other: 2. Movable bridge ☒ Electric brakes ☒ Motors and power ☒ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☐ Crack/fracture ☐ Expansion/contraction ☐ Rotation/torsion ☐ Wear/spalling/scaling/delamination
☐ Section loss ☐ Settlement ☐ Misalignment ☐ Connection failure or deficiencies
☐ Deformation ☐ Wire breakage ☐ Mechanical/electrical malfunction ☐ Impact damage
☐ Debonding ☐ Erosion/scour ☐ Looseness and pounding ☐ Excessive joint closing/opening
☐ Corrosion ☒ Environmental ☐ Other:

Measurement Metric

☐ Strain ☐ Deflection/displacement ☐ Acceleration/vibration ☐ Moisture/humidity level
☒ Temperature ☐ Magnetic field/flux ☐ Electrical voltage/current ☐ Chemical composition
☐ Radar waves ☐ Acoustic waves ☐ Magnetic waves ☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☐ Wind speed/direction ☐ Other:

3. Cost		
Hardware	Sensor	Model 22802-S-36: $124.8 per unit. Model 22810:$72 (1-B-12), $84 (1-C-36) per unit. Model 22391-T01-B-12: $67.2 per unit. Model 22392: $115.2 (T10-A-12), $121.2 (T01-B-12), $123.6 (T01-B-24) per unit. Model 22393: $96 (T01-B-12-0), $98.4 (T10-B-18-0) per unit. Model 22489-3-A-0: $200 per unit.
	Data acquisition system	
	Communication system	
	Data archiving system	
	Other	
Software		
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	No official life expectancy.
Power	
Environmental conditions	Model 22810 and 22391/2/3: -200 to 232°C. Model 22802: -200 to 260°C for "S (standard)", 0 to 480°C for "H (high)". Model 22488/9: -270 to 260°C.
Data storage/transfer/ processing	Depends on products.
Other: Accuracy: ±0.22 ohms to 0.5 ohms (or 0.25% to 0.50% of temperature).	

5. Implementation Needs	
Power source	
Accessibility	Direct access needed for sensor installation.
Technical expertise	Basic instrumentation skills.
Other:	

6. Availability
1 to 2 weeks if available in stock. Otherwise, 5 to 7 weeks.

7. On-Going or Completed Bridge Related Projects and References
Bridge monitoring prodects by Connecticut DOT.

8. Notes
• RdF Corporation was founded in 1939 and is certified to AS9100 ISO 9001-2000. • RdF Corporation designs, produces and develops various temperature sensors and thermocouples.

1. General Information

Description of Technology	Inclinometers (tilt monitoring and slope measurement) and other sensors.		
Manufacturer and Contact information	Rieker Inc. PO Box 128, Folcroft, PA 19032	www.riekerinc.com Tel: (610) 534-9000 Fax: (610) 534-4670	
Features	Sensor type	SB2i and SB2g inclinometer package (Inclination ranges: ±4° to ±80°, Silicon RTV Filled, symmetrical or oblique measurement ranges): the SB2i and SB2g provide dual axis inclination or acceleration measurement in an environmentally protected housing.	
	Data acquisition, processing, and archiving		
	Communications		
	'Smart' attributes		
	Other	SB2g measures movements under 2 inches for pier heights of near 250 to 300 ft. SB2i is used for smaller pier height (around 150 ft).	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☐ Multi-beam/girder system: ☐ Girder floor beam/diaphragm system ☐ Tee beam ☐ Box girder ☐ Channel beam ☐ Slab ☐ Truss member ☐ Arch element ☐ Other:					
	Secondary Element ☐ Connector and fastener: ☐ Riveted/bolted ☐ Welded ☐ Pin & hanger ☐ Splice ☐ Bracing: ☐ Cross ☐ Lateral ☐ Sway ☐ Diaphragm ☐ Cover plate ☐ Stiffener ☐ Other:					
	Bearing ☐ Fixed ☐ Expansion: ☐ Sliding plate ☐ Roller ☐ Rocker ☐ Pin and link ☐ Elastomeric ☐ Pot ☐ Restraining ☐ Other:					
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☐ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☐ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☐ Main/secondary cable ☐ Cable anchorage ☐ Anchor rod ☐ Damping system ☐ Strand shoes ☐ Cable bands ☐ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☐ Crack/fracture	☐ Expansion/contraction	☒ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☐ Section loss	☐ Settlement	☒ Misalignment	☐ Connection failure or deficiencies
☐ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☐ Impact damage
☐ Debonding	☐ Erosion/scour	☐ Looseness and pounding	☐ Excessive joint closing/opening
☐ Corrosion	☐ Environmental	☒ Other: Tilt and slope change.	

Measurement Metric

☐ Strain	☒ Deflection/displacement	☐ Acceleration/vibration	☐ Moisture/humidity level
☐ Temperature	☐ Magnetic field/flux	☐ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☒ Other: Angles.	

3. Cost		
Hardware	Sensor	Inclinometer package : $908 (4-20mA output) ~ $968 (0-5V DC output) per unit. Sensors are provided with one-year warranty.
	Data acquisition system	
	Communication system	
	Data archiving system	
	Other	
Software		
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	No official life expectancy.
Power	Single 10 to 30V DC Input. 4 to 20 mA Output.
Environmental conditions	-40°C to 85°C. IP65 Environmental Protection.
Data storage/transfer/ processing	Depends on products.
Other:	

5. Implementation Needs	
Power source	DC.
Accessibility	Direct access needed for sensor installation.
Technical expertise	Basic instrument handling skills.
Other:	

6. Availability

6 to 8 weeks.

7. On-Going or Completed Bridge Related Projects and References

Information not available.

8. Notes

- Since 1917, Rieker has manufactured and provided durable, weatherproof tilt measuring, and leveling instruments.
- The sensing package incorporates a modular design allowing users to select the measurement range and sensor for each axis that suits the individual application.
- Both symmetrical (±3g) and oblique (-15° to 70°) ranges are available for tilt and acceleration measurements.
- A complete sensor package is comprised of a measurement sensor; two internally regulated power supplies; separate signal conditioners for 4 to 20 mA current or 0 to 5V DC voltage output operation; separate active low pass filtering for high frequency noise suppression.
- The filter's upper frequency and time constant can be customized to suit a wide range of requirements.

1. General Information

Description of Technology	Automated, customized structural health monitoring system.		
Manufacturer and Contact information	Roctest Telemac Ltd. 665 Pine Avenue, Saint-Lambert, QC, Canada, J4P 2P4	www.roctest.com Tel: (450) 465-1113 or (877) 762-8378 Fax: (450) 465-1938	
Features	Sensor type	Strain gage, temperature sensor, tiltmeter, thermocouples, load cells, fiber optic sensor (FOS) - strain, displacement, settlement gage, etc.	
	Data acquisition, processing, and archiving	Manual or automatic data acquistion system. SENSLOG 1000X data acquisition system. Windows based data acquistion software (FISO). Programmable loggers. Multi-channel data collecting system. PC with data processing software and remote data monitoring system.	
	Communications	Flexible data retrieval (direct wire connection, telehpone line, radio telemetry, coaxial cable, modem or satellite).	
	'Smart' attributes	Automated monitoring with alarm capabilities.	
	Other	Gages can be surface-mounted or embedded in a variety of materials including steel, concrete and composite materials. Multiplexer connects up to 32 sensors to the control module.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☒ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☒ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☒ Main/secondary cable ☒ Cable anchorage ☒ Anchor rod ☒ Damping system ☒ Strand shoes ☒ Cable bands ☒ Cable enclosures ☐ Other: 2. Movable bridge ☒ Electric brakes ☒ Motors and power ☒ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☒ Crack/fracture	☒ Expansion/contraction	☒ Rotation/torsion	☒ Wear/spalling/scaling/delamination
☒ Section loss	☒ Settlement	☒ Misalignment	☒ Connection failure or deficiencies
☒ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☒ Impact damage
☒ Debonding	☐ Erosion/scour	☐ Looseness and pounding	☐ Excessive joint closing/opening
☒ Corrosion	☐ Environmental	☐ Other:	

Measurement Metric

☒ Strain	☒ Deflection/displacement	☐ Acceleration/vibration	☒ Moisture/humidity level
☒ Temperature	☐ Magnetic field/flux	☒ Electrical voltage/current	☒ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☒ Other: Hydraulic pressure.	

3. Cost		
Hardware	Sensor	Depends on the size of project (example: $25,000 for 16 strain gage monitoring with DAS system and 3,200 ft cable).
	Data acquisition system	
	Communication system	
	Data archiving system	
	Other	
Software		
Labor	Installation	Depends on site and condition (example: $6,000 for 16 gage installation under normal conditions).
	Use	
Other:		

4. Limitations	
Life expectancy	No official life expectancy.
Power	Model 796 (110/120V AC or 220/240V AC. Power output: 12V DC. Two internal 12V rechargable batteries provide backup power during AC power outages). SENSLOG 1000X (9.6 to 16V and 12V batteries).
Environmental conditions	Typically -25°C to 50°C (wider range available), 0 to 100% relative humidity (non condensing). System is protected from transients using spark gaps or transzorbs.
Data storage/transfer/ processing	128 Kbytes of memory standard (expandable to 2 Mbytes).
Other:	

5. Implementation Needs	
Power source	Battery, AC/DC, solar panel.
Accessibility	Direct access or remote monitoring and control.
Technical expertise	Basic electronic and computer skills, knowledge of bridge engineering. Minimal training required for system installation and data control/management.
Other: Windows based PC (Pentium II or higher processor).	

6. Availability

Upon agreement.

7. On-Going or Completed Bridge Related Projects and References

Morristown Bridge, Vermont, 2002.
Patroon Island Bridge, New York, 2001.
Rollinsford Bridge, New Hampshire, 2000.
Joffre Bridge, St-Emilie Bridge, Wellington Bridge, Watton Bridge, Canada.
Many others in many countries.

References:

- El-Salakawy, E., Kassem, C., and Benmokrane, B. "Filed Applicatiton of FRP Composite Bars as Reinforcement for Bridge Decks," 4th Structural Specialty Conference of the Canadian Society for Civil Engineering, Montreal, Quebec, Canada, June 5-8, 2002.
- Choquet, P., Juneau, F., and Bessette, J. "New Generation of Fabry-Perot Fiber Optic Sensors for Monitoring Structures," Proceedings of SPIE, 7th Annual International Symposium on Smart Structures and Materials, Newport Beach, California, March 5-9, 2000.

8. Notes

- Founded in 1967 and active in 75 countries, Roctest is specialized in the production of instrumentation (measuring/monitoring equipment and inductive sensors) used in large civil engineering projects.
- Roctest's system is fully programmable directly or remotely.
- Monitoring system is compatible to most common types of instruments and vibrating wire transducers.

1. General Information

Description of Technology	Corrosion Monitoring System: monitoring corrosion risk of steel in concrete; monitoring the ingress of chlorides and carbonation, as well as time-to-corrosion.	
Manufacturer and Contact information	S+R Sensortec GmbH Liefenweg 15, D-52078 Aachen, Germany	www.sensortec.de Tel: + 49-241-37252 Fax: + 49-241-37253
Features – Sensor type	Multiring electrodes (can be used for both new and existing structures). PT 1000 (temperature sensor). Other sensors (Anode-Ladder and Expansion ring) are included in Anode-Ladder system and Expansion ring system.	
Features – Data acquisition, processing, and archiving	Anode-Ladder system (for new structures), Expansion ring system (for existing structures; drilled holes), CANIN LTM (corrosion analysis instrument for long-term monitoring; measures data from the sensors at the terminal-box, stores, and transfers data to a PC), Data processing software (Microsoft EXCEL can also be used)	
Features – Communications	Direct cable connection. Wireless communication can be designed upon request.	
Features – 'Smart' attributes	Automatic data measurement and display: the potentials, corrosion currents, concrete resistances and temperature are measured, stored and displayed automatically.	
Features – Other	Also available is a continuous monitoring system with datalogger writing on SD-Cards or with remote data transmission via GSM.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☐ Timber:	☐ Plank ☐ Other:	☐ Nailed laminated	☐ Glue-laminated	☐ Prestressed laminated	☐ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☐ Steel:	☐ Grid ☐ Other:	☐ Orthotropic	☐ Buckle plate	☐ Corrugated steel flooring	
	☐ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☐ Connector and fastener: ☐ Bracing: ☒ Diaphragm ☐ Cover plate ☐ Stiffener ☐ Other:	☐ Riveted/bolted ☐ Cross	☐ Welded ☐ Lateral	☐ Pin & hanger ☐ Sway	☐ Splice	
	Bearing ☐ Fixed ☐ Expansion: ☐ Other:	☐ Sliding plate	☐ Roller	☐ Rocker	☐ Pin and link	☐ Elastomeric ☐ Pot ☐ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☐ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☒ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☐ Strand shoes 2. Movable bridge ☐ Electric brakes	☐ Main/secondary cable ☐ Cable bands ☐ Motors and power	☐ Cable anchorage ☐ Cable enclosures ☐ Operating machinery and equipment	☐ Anchor rod ☐ Other:	☐ Damping system ☐ Other:	
	Other:					

Monitoring Interest

☐ Crack/fracture	☐ Expansion/contraction	☐ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☐ Section loss	☐ Settlement	☐ Misalignment	☐ Connection failure or deficiencies
☐ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☐ Impact damage
☐ Debonding	☐ Erosion/scour	☐ Looseness and pounding	☐ Excessive joint closing/opening
☒ Corrosion	☒ Environmental	☐ Other:	

Measurement Metric

☐ Strain	☐ Deflection/displacement	☐ Acceleration/vibration	☒ Moisture/humidity level
☒ Temperature	☐ Magnetic field/flux	☒ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☐ Other:	

3. Cost		
Hardware	Sensor	
	Data acquisition system	
	Communication system	
	Data archiving system	
	Other	
Software		
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	±100 years of designed and expected lifetime of the sensors and cables embedded in concrete.
Power	6 x 1.5V Batteries (Type AA).
Environmental conditions	Termperature measurement range: ±99°C with ± 2°C accuracy.
Data storage/transfer/ processing	PC with Microsoft EXCEL Software.
Other: Potential measurement range: +999mV with ±2mV accuracy. Current measurement range: +999µA with ±10µA accuracy. Resistance measurement range: 0-100 kΩ with ±0.5 kΩ accuracy. 1000 complete measurements can be stored in the CANIN LTM and a maximum of 72 different sensor numbers can be assigned.	

5. Implementation Needs	
Power source	Battery.
Accessibility	Direct access needed for sensor installation and data acquisition (remote monitoring system is available upon request).
Technical expertise	Basic instrumentation handling skills and knowledge of corrosion monitoring. Minimal training (manual is available on website for free).
Other:	

6. Availability

Upon agreement.

7. On-Going or Completed Bridge Related Projects and References

DRK-Bridge, Croatia, 2003.
Testing of bridge caps with new type of cement, BAST, Germany, 1998.
Oresund-Link Bridge, Sweden and Denmark, 1998.
Great Belt-Link Bridge, Denmark, 1994.
Notsch Bridge, Austria, 1991.

References;

- Raupach, M.: "Determination of the Time-to-Corrosion of Concrete Structures," ICACS 2003, International Conference, Advances in Concrete and Structure, September 17-19, 2003, Xuzhou, China.
- Klinghoffer, O., Goltermann, P., and Bassler, R. "Smart Structures: Embeddable Sensors for Use in the Integrated Monitoring Systems of Concrete Structures," 1st International Conference on Bridge Maintenance, Safety and Mangement, IABMAS 2002, Barcelona, Spain, July 14-17, 2002.
- Raupach, M.: "Corrosion Behaviour of the Reinforcement under On-Site-Conditions," Granada: Minstry of Science and Technology, 2002. – In: 15th International Corrosion Congress, Frontiers in Corrosion Science and Technology, Granada, September 22-27, 2002.
- Ramboll Denmark. "Integrated Monitoring Systems for Durability Assessment of Concrete Structure" Smart Structures Project Report, Contract No. BRPR-CT98-0751, September 2002.
- Other references are available on company website.

8. Notes

- S+R Sensortec GmbH provides design and service of their corrosion monitoring systems (oversea service available).
- The company offers services including: Development of concepts for maintenance and monitoring of concrete structures; Planning and detailed design of monitoring-systems, especially for corrosion; Installation of the Sensor-Systems; Training and supervision of installations on site; Measurements on site; Evaluation and interpretation of the data.

1. General Information

Description of Technology	Fiber Bragg Grating (FBG) monitoring sensors and measuring devices.	
Manufacturer and Contact information	SiF Universal Pte Ltd 41 Science Park Road, #01-16 The Gemini, Singapore 117610	www.sif-u.com Tel: +(65) 6773 9366 Fax: +(65) 6774 6040
Features	Sensor type	FBG sensors (immunte to EMI/RFI; self calibrating; no need for reference sensor; low insertion loss). Embedded concrete strain sensor. Temperature sensor.
	Data acquisition, processing, and archiving	Data logger: system can be set up for remote sensing and processing. FBG sensors can be instantaneously (immediate readings of up to 250Hz), simultaneously (all data points collected at one time) and continuously (24 hrs a day, 7 days a week) monitored.
	Communications	Direct wire connection, modem, Internet, or other communication protocols upon request.
	'Smart' attributes	
	Other	FBG sensors are about 40 mm long, 5 mm wide and 0.5 mm thick, and can undergo 4,000 micro strains. Single cable can incorporate up to 30 sensors.

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☒ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☐ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☐ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☒ Main/secondary cable ☒ Cable anchorage ☒ Anchor rod ☒ Damping system ☒ Strand shoes ☒ Cable bands ☒ Cable enclosures ☐ Other: 2. Movable bridge ☒ Electric brakes ☒ Motors and power ☒ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☒ Crack/fracture	☐ Expansion/contraction	☒ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☐ Section loss	☒ Settlement	☒ Misalignment	☐ Connection failure or deficiencies
☒ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☒ Impact damage
☐ Debonding	☐ Erosion/scour	☐ Looseness and pounding	☐ Excessive joint closing/opening
☐ Corrosion	☒ Environmental	☒ Other: Seismic response	

Measurement Metric

☒ Strain	☒ Deflection/displacement	☒ Acceleration/vibration	☐ Moisture/humidity level
☒ Temperature	☐ Magnetic field/flux	☐ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☐ Other:	

3. Cost		
Hardware	Sensor	FBG sensor: $200 per unit. Embedded concrete strain sensor: $800 per unit. Temperature sensor: $150 per unit.
	Data acquisition system	Data logger: $15,000~$40,000.
	Communication system	
	Data archiving system	
	Other	
Software	$1,000.	
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	Long term stability. Minimum of 20 years.
Power	110/220V AC.
Environmental conditions	-40°C to 250°C.
Data storage/transfer/ processing	Standard Windows-based PC.
Other:	

5. Implementation Needs	
Power source	Battery, AC/DC.
Accessibility	Direct access needed for sensor installation. Direct or remote data acquisition.
Technical expertise	Basic electronics and computer skills, knowledge of dynamics.
Other:	

6. Availability
6 to 10 weeks.

7. On-Going or Completed Bridge Related Projects and References
Information not available.

8. Notes
• SiF-Universal's products are based on the fiber bragg grating technology; the applications range from structural health monitoring for civil and geotechnical engineering to process monitoring for oil and gas production. • The company offers custom designed products. • 1000 sensors can be linked to a single data acquisition unit where data interpretation can take place.

1. General Information

Description of Technology	MEMS accelerometers and acceleration data acquisition system.		
Manufacturer and Contact information	Silicon Design, Inc. (SDI) 1445 NW Mall St., Issaquah, WA 98027	www.silicondesigns.com Tel: (425) 391-8329 Fax: (425) 391-0446	
Features	Sensor type	Model 1210: for use in zero to medium frequency instrumentation applications. Model 2210: combines an integrated Model 1210L accelerometer with high drive, low impedance buffering.	
	Data acquisition, processing, and archiving	G-LOGGERTM system (3.5" x 4.5" x 2.2" Water Tight, Die Cast Aluminum Case): self-contained, sealed from the weather; up to 3 weeks unattended operation on D-cell alkaline batteries; connects to PC serial port for programming & data reporting; logs acceleration, shock, vibration, velocity & temperature; programmable data capture (timed, continuous or event centered).	
	Communications		
	'Smart' attributes		
	Other	Model 2220 Accelerometer Module: lower noise version of 2210 with tighter tolerances & wider temperature range capactive acclerometers.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☐ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☐ Riveted/bolted ☒ Cross	☐ Welded ☒ Lateral	☐ Pin & hanger ☒ Sway	☐ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☐ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☐ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☐ Strand shoes 2. Movable bridge ☐ Electric brakes	☐ Main/secondary cable ☐ Cable bands ☐ Motors and power	☐ Cable anchorage ☐ Cable enclosures ☐ Operating machinery and equipment	☐ Anchor rod ☐ Other:	☒ Damping system ☐ Other:	
	Other:					

Monitoring Interest

☐ Crack/fracture	☐ Expansion/contraction	☐ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☐ Section loss	☐ Settlement	☐ Misalignment	☐ Connection failure or deficiencies
☐ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☒ Impact damage
☐ Debonding	☐ Erosion/scour	☐ Looseness and pounding	☐ Excessive joint closing/opening
☐ Corrosion	☐ Environmental	☒ Other: Wind effect, seismic activity.	

Measurement Metric

☐ Strain	☐ Deflection/displacement	☒ Acceleration/vibration	☐ Moisture/humidity level
☒ Temperature	☐ Magnetic field/flux	☐ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☐ Other:	

3. Cost		
Hardware	Sensor	
	Data acquisition system	
	Communication system	
	Data archiving system	
	Other	
Software		
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	No official life expectancy.
Power	Model 1210: 5 VDC, 7mA Power (typical). Model 2210 and 2220: 9 to 32V DC.
Environmental conditions	Model 1210 and 2220: -55 to 125°C. Model: 2210: -40 to 85°C.
Data storage/transfer/ processing	Depends on products and specifications.
Other: Model 2220: Digital 100 to 1000 kHz Clock Frequency; Analog ±4V Differential or 0.5 to 4.5V Single Ended; ± 1% operational linearity; overshock resistance to 10,000 g.	

5. Implementation Needs	
Power source	Battery, AC/DC.
Accessibility	Direct access or remote monitoring.
Technical expertise	Minimal. Basic electronics skills.
Other:	

6. Availability

2 to 4 weeks for standard products.

7. On-Going or Completed Bridge Related Projects and References

Steel Truss Bridge at University of California, Irvine, California.
Golden Gate Bridge, San Francisco, California.

References:

- Lynch, J., Law, K., Kiremidjian, A., Carryer, E., Kennedy, T., partridge, A., and Sundararajan, A. (2002): "Validation of a wireless modular monitoring system for structures," the SPIE 9th Annual International Symposiums on Smart Structures and Materials, San Diego, CA, March 17-21, 2002.
- High Performance Wireless Research and Education Network (HPWREN), http://hpwren.uscd.edu
- Chung, H.C., Enomoto, M., Loh, K., and Shinozuka, M. "Real Time Visualization of Structural Response through Wireless Communication using MEMS Sensors," Proceedings of SPIE: Testing, Reliability, and Application of Micro- and Nano-Material Systems II, Vol. 5392, pp. 239-246, July 2004.

8. Notes

- Founded in 1983, Silicon Designs has provided products and services including analog and digital output accelerometers; stand-alone, instrumentation grade single and 3-axis accelerometer modules; self contained, battery operated, microprocessor based data loggers, thin film links and resistors, slapper detonators, micro-sensors, and contact fuse/impact sensors.
- The company is also capable of electronic, circuit, system, and product design; micro-machining and thin-film development; ASIC, hybrid, micro-sensor, and PC board design.
- G-LOGGERTM system was originally designed as a vibration monitor for NASA and the Space Shuttle Program.

1. General Information

Description of Technology	Geotechnical and structural monitoring system.		
Manufacturer and Contact information	Slope Indicator 12123 Harbour Reach Dr.,Mukilteo, WA, 98275	www.slopeindicator.com Tel: (425) 493-6200 Fax: (425) 493-6250	
Features	Sensor type	EL Beam sensor, EL tiltmeter (electrolytic tilt sensors, a precision bubble-level that is sensed electrically as a resistance bridge, capable of measurements of as small as 0.005mm). Other sensors also available (strain gages, temperature sensor, jointmeters, etc).	
	Data acquisition, processing, and archiving	CR10X Automatic data acquisition system (a complete data acquisition system consisting of data logger components, data retrieval components, and software components): capable of 16 to 32 channels with mutiflexer.	
	Communications	Direct wire connection, telephone line, modem, Internet or satellite.	
	'Smart' attributes	Near real-time, continuous monitoring system with alarm triggering capability when preset limit is exceeded (user can be notified by an e-mail, phone or by pager).	
	Other	Multimon and GraphX software (collects all data from the data logger and post all the information on a web site). Readings can be downloaded manually onto a PC or remotely by a phone line or digital modem.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☐ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☐ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☐ Cover plate ☒ Stiffener ☐ Other:	☐ Riveted/bolted ☐ Cross	☐ Welded ☐ Lateral	☐ Pin & hanger ☐ Sway	☐ Splice	
	Bearing ☐ Fixed ☐ Expansion: ☐ Other:	☐ Sliding plate	☐ Roller	☐ Rocker	☐ Pin and link	☐ Elastomeric ☐ Pot ☐ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☐ Shaft	☒ Column/stem	☐ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☐ Strand shoes 2. Movable bridge ☐ Electric brakes	☐ Main/secondary cable ☐ Cable bands ☐ Motors and power	☐ Cable anchorage ☐ Cable enclosures ☐ Operating machinery and equipment	☐ Anchor rod ☐ Other:	☐ Damping system ☐ Other:	
	Other:					

Monitoring Interest

☒ Crack/fracture	☐ Expansion/contraction	☒ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☐ Section loss	☒ Settlement	☒ Misalignment	☐ Connection failure or deficiencies
☒ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☐ Impact damage
☐ Debonding	☐ Erosion/scour	☐ Looseness and pounding	☐ Excessive joint closing/opening
☐ Corrosion	☐ Environmental	☐ Other:	

Measurement Metric

☒ Strain	☒ Deflection/displacement	☐ Acceleration/vibration	☐ Moisture/humidity level
☒ Temperature	☐ Magnetic field/flux	☐ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☐ Other:	

3. Cost		
Hardware	Sensor	EL sensor (w/ or w/o signal conditioning): $400~$480 per unit.
	Data acquisition system	EL Data Recorder (hand held readout): $1,500. Automatic Data Logger (CR10X): $3,000-$6,000.
	Communication system	
	Data archiving system	
	Other	Need to add aluminum beam price to sensor prices, which depend on its gauge length, 3 or 6 ft.
Software	Free (available on their website).	
Labor	Installation	
	Use	
Other: Price of data logger depends on accessories and quantity of sensors to be read.		

4. Limitations	
Life expectancy	10 years plus.
Power	12V regulated power source.
Environmental conditions	-20°C to 55°C.
Data storage/transfer/ processing	Depends on products and specification.
Other:	

5. Implementation Needs	
Power source	AC, solar pannel.
Accessibility	Direct access or remote monitoring.
Technical expertise	Minimal. Traning and technicians are available for assistance.
Other:	

6. Availability

2 to 3 weeks from receipt of order.

7. On-Going or Completed Bridge Related Projects and References

Hoover Dam Bypass - Colorado River Bridge, Nevada.
High-Speed Railway Bridge, Taiwan
Church Street Bridge, Melbourne, Australia.

8. Notes

- Slope Indicator manufactures a wide range of geotechnical and structural sensors for monitoring tilt, displacement, pressure, and strain. The company also supplies data acquisition systems and software for real-time processing and graphical presentation of data.
- Slope Indicator offers a variety of instrumentation courses including a course on inclinometer data reduction and error correction.
- Slope Indicator can provide logging programs for those who need to implement the monitoring system quickly or who are uncomfortable with programming.

1. General Information

Description of Technology	Structural health monitoring system based on optical fibre sensing technologies.		
Manufacturer and Contact information	Smart Fibres Ltd. C3 Centennial Ct, Easthampstead Rd, Bracknell, Berkshire, UK	www.smartfibres.com Tel: +44 (0) 1344 484111 Fax: +44 (0) 1344 423241	
Features	Sensor type	Smart fiber bragg grating (FBG) Sensors, SmartPatch, SmartTape, SmartCell, SmartRod, SmartWeld. SmartPipe.	
	Data acquisition, processing, and archiving	FBG interrogator (W3 and F3/2005, W4, and T4 range) provides deterministic data interrogation. Data processing with a laptop PC. SmartSoft (LabView based) provides up-to-date information in a variety of formats and allows for simple on-line calibration, data display and logging of the FBGs.	
	Communications	Direct wire connection, modem, Internet or satellite.	
	'Smart' attributes	Real-time, continuous monitoring with optional alarm triggering system.	
	Other	System can be designed to meet various bridge monitoring requirements.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☐ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☒ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☐ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☒ Main/secondary cable ☒ Cable anchorage ☒ Anchor rod ☒ Damping system ☒ Strand shoes ☒ Cable bands ☒ Cable enclosures ☐ Other: 2. Movable bridge ☒ Electric brakes ☒ Motors and power ☒ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☒ Crack/fracture	☐ Expansion/contraction	☐ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☐ Section loss	☒ Settlement	☐ Misalignment	☐ Connection failure or deficiencies
☒ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☒ Impact damage
☐ Debonding	☐ Erosion/scour	☐ Looseness and pounding	☐ Excessive joint closing/opening
☐ Corrosion	☐ Environmental	☐ Other:	

Measurement Metric

☒ Strain	☒ Deflection/displacement	☒ Acceleration/vibration	☐ Moisture/humidity level
☒ Temperature	☐ Magnetic field/flux	☐ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☒ Other: Pressure.	

3. Cost		
Hardware	Sensor	FBG-unpackaged: $109~$195 per unit. SmartPatch: $301~$500 per unit. SmartTape: $139~$412 per unit. SmartRod: $794~$7,741 per unit. SmartCell: $390~$1,480 per unit. SmartPipe: $188~$553 per unit.
	Data acquisition system	Interrogators. W4: $10,395~$13,640. F3: $10,805~$43,991. W3: $11,970~$43,991. T4: $5,545~$14,952.
	Communication system	
	Data archiving system	
	Other	Variable depending on number of channel, capacity and volume of order.
Software	Free version is included in interrogators. Others depend on application (how it is customised).	
Labor	Installation	
	Use	
Other: Volume discounts and rentals are available upon request.		

4. Limitations	
Life expectancy	25 years plus. Tests with carbon fibre coupons have shown that embedded fibre sensors show no signs of fatique or disbonding after one million cycles.
Power	W4 Range: 12V DC or 110/220V AC (electrical supply). 15W typical (power consumption). W3 Series: 24V DC or 110/220V AC (electrical supply). 75W typical and 150W max (power consumption). F3/2005: 110/220V AC.
Environmental conditions	Sensors: -50°C to 85°C (typical), -100°C to 300°C (max). Interrogator: 10°C to 40°C. Wider range available on request.
Data storage/transfer/ processing	
Other:	

5. Implementation Needs	
Power source	AC/DC.
Accessibility	Direct access or remote monitoring and control.
Technical expertise	Engineering background. Training for data management is available.
Other:	

6. Availability
4 to 6 weeks depending on volume of order.

7. On-Going or Completed Bridge Related Projects and References
Monitoring of composite bridge deck and concrete shear wall: University of California, Irvine, 2001. Millennium Dome, London, 2000. Many other projects in many countries.

8. Notes
• Since 1995, Smart Fibres has developed and provided structural health monitoring products and engineering services including FBG interrogation units developed in-house and, through a strategic alliance with Micron Optics Inc. (www.micronoptics.com); Smart Fibres offers and supports Micron Optics' complete product range on highly competitive terms. • The company also offers engineering expertise to evaluate requirements and help specify configuration of monitoring system; provides help with the installation and commissioning, and trainning to manage and evaluate data. • The company has also developed a range of packaged sensors for measuring strain, temperature and pressure in harsh environments and for embedment or surface mounting to all manner of substrates. • Hundreds of FBG sensors can be recorded onto a single optical fibre and interrogated simultaneously with a single instrument.

1. General Information

Description of Technology	Advanced global health monitoring system based on fiber optic sensing technologies (SOFO monitoring system): measuring deformations over long measurement bases.		
Manufacturer and Contact information	SMARTEC Via Pobiette 11, CH-6928 Manno, Switzerland	www.smartec.ch Tel: +41 91 610 18 00 Fax: +41 91 610 18 01	
Features	Sensor type	Fiber optic sensor (FOS): concrete setting sensor, deformation sensor, inclinometer, strain sensor, thermocouple. SOFO sensor: capable of measuring deformations over long measurement bases.	
	Data acquisition, processing, and archiving	Data acquisition (SOFO, Bee, ADAM, DiTeSt): can be programmed to automatically collect data. Data management, analysis and publishing (SOFO SDB): automatic and scheduled measurements and real-time, simultaneous display of several different views within the same window.	
	Communications	Direct wire connection, modem, telephone line, pager, radio, Internet, satellite, or other communication options upon request.	
	'Smart' attributes	Real-time, continuous and autonomous operation system capable of management of warning states in the form of pre-warning and thresholds. It triggers alarm based on user-defined action (sound, phonecall, e-mail, etc.).	
	Other	Sensors immune or insensitive to electromagnetic fields, humidity, vibrations and corrosion. No calibration required. Waterproof.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☒ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☒ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☒ Main/secondary cable ☒ Cable anchorage ☒ Anchor rod ☒ Damping system ☒ Strand shoes ☒ Cable bands ☒ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☒ Crack/fracture ☒ Expansion/contraction ☒ Rotation/torsion ☐ Wear/spalling/scaling/delamination
☐ Section loss ☒ Settlement ☒ Misalignment ☐ Connection failure or deficiencies
☒ Deformation ☐ Wire breakage ☐ Mechanical/electrical malfunction ☒ Impact damage
☐ Debonding ☐ Erosion/scour ☐ Looseness and pounding ☒ Excessive joint closing/opening
☐ Corrosion ☒ Environmental ☒ Other: Seismic activity, prestress losses.

Measurement Metric

☒ Strain ☒ Deflection/displacement ☐ Acceleration/vibration ☐ Moisture/humidity level
☒ Temperature ☐ Magnetic field/flux ☐ Electrical voltage/current ☐ Chemical composition
☐ Radar waves ☐ Acoustic waves ☐ Magnetic waves ☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☐ Wind speed/direction ☒ Other: Seismic waves, solar irradiation.

3. Cost		
Hardware	Sensor	SOFO sensor: $1,106~$2,282 per unit ($1.00 = CHF1.24). SOFO concrete setting sensor: $1,434 per unit. Inclinometer: $4,340~$4,565 per unit. Termocouples-temperature sensor: $165 per unit.
	Data acquisition system	SOFO V reading unit with DB software: $65,844 (1 channel) ~ $86,428 (12 channels). SOFO Bee with SDB software: $61,752 (12 chennels) ~ $71,548 (24 channels).
	Communication system	Variable.
	Data archiving system	Variable.
	Other	Junction box: $583 (1 to 10 sensors) ~ $1,091 (1 to 36 sensors). SOFO optical switch with 20 channels: $32,054.
Software	SOFO VIEW (graphic display and warning alert): $357/month ~ $2,852/license. SOFO PRO (real-time analysis and data interpretation): $388/month ~ $3,100/license. SOFO SPADS (curvature analysis): $876/month ~ $7,006/license. SOFO SDB (including PRO, VIEW and SPADS): $10,701/license.	
Labor	Installation	Variable.
	Use	SOFO traning course: $2,604. Support: $174 (engineer) ~ $217 (manager)/hour.
Other: Certificate of origin SOFO: $310. Accessories: variable (e.g., connecting cable, standard active part, junction cable, power supply, upgrade memory, other updates, etc).		

4. Limitations	
Life expectancy	20 years plus (depends on products)
Power	SOFO reading unit: 230V 50Hz/110V 60Hz AC, 12V DC rechargeable batteries. SOFO dynamic reading unit: 115/235V AC.
Environmental conditions	Sensors: -40°C to 80°C; maximum of -65°C to 300°C for temperature sensor. SOFO Reading units: -20°C to 60°C (operating), -30°C to 70°C (storage), 90% relative humidity (non-condensed). Dynamic reading unit: 0 to 30°C.
Data storage/transfer/ processing	Data logger capacity: typical 20,000 measurements, minimal 8,000 measurements (4 Mb flash memory); up to 320,000 measurements with 64 Mb flash memory.
Other: Measurement time: <10 sec. Measurement resolution: 2µm RMS. Dynamic range: Max. 50 mm.	

5. Implementation Needs	
Power source	Battery, AC/DC, or solar panel (can last 8 days without sun light).
Accessibility	Automatic and remote monitoring and control.
Technical expertise	Moderate training for system installation and control. Training course is available.
Other: PC with a minimum of Pentium II processor, 128MB RAM, 50MB hard disk, 800x600 display. SOFO SDB requires Windows 95/98/2000/NT/XP or newer version; Microsoft EXCEL and ACCESS are recommended to export the data for further analysis and representation, but not required to run SOFO SDB.	

6. Availability

2 to 6 weeks.
Some equipment available for rental.

7. On-Going or Completed Bridge Related Projects and References

Arsta Bridge, Sweden, 2003.
Soolshoi Moskvoretskiy Bridge, Russia, 2003.
Schladming Bridge, Austria, 2002.
Kameura Bridge, Japan, 2001.
Rio Puerco Bridge, New Mexico, 2000.
Colle Isarco Bridge, Italy, 1999.
Horsetail Fall Bridge, Oregon, 1998.
Many other bridge monitoring projects in many countries.

References:

- Lienhart, W., and Brunner, F.K. "Monitoring of Bridge Deformations Using Embedded Fiber Optical Sensors," Proceedings, 11th FIG Symposium on Deformation Measurements, Santorini, Greece, 2003.
- Vurpillot, S., Inaudi, D., and Ducret, J.M. "Bridge Monitoring by Fiber Optic Deformation Sensors: Design, Emplacement and Results," Smart Structures and Materials, Proceedings of SPIE, San Diego, CA, 1996.
- Numerous case studies and references are available on company website.

8. Notes

- Founded in 1996, SMARTEC SA is a developer, producer and distributor of measurement and structural health monitoring systems; the company's products range from sensors (fiber optic, GPS and conventional) and data acquisition systems to software for data management and analysis.
- SMARTEC offers support and training in the design, installation, use of monitoring systems, and the management and analysis of the resulting data.
- SOFO Monitoring System: measuring deformations over long measurement bases, with a micrometer resolution with long-term stability.
- SOFO Dynamic Monitoring System (8 channels): designed to perform dynamic measurements at high frequencies (DC to 1000 Hz) providing high resolution.
- DiTeSt System: a unique tool for the monitoring of distributed strain and/or temperature over several kilometers, allowing the measurement of thousands of locations at once by means of a single optical fiber end. The DiTeSt is a laser based measurement system using an optical interaction measurement principle with the sensing fiber: stimulated brillouin scattering.

1. General Information

Description of Technology	3 Dimensional deformation monitoring network (3DeMoN): a GPS-based technology system used for permanent monitoring of millimeter-scale movements; flexible and re-configurable; quick installation; weather independent; 3D displacement monitoring.	
Manufacturer and Contact information	SMARTEC Via Pobiette 11, CH-6928 Manno, Switzerland	www.smartec.ch Tel: +41 91 610 18 00 Fax: +41 91 610 18 01
Features	Sensor type	Autonomous laser distance meters, GPS receivers.
	Data acquisition, processing, and archiving	The measurement and reference stations are physically identical. The data received from all the measurement and reference stations is processed simultaneously and the relative movement between the stations is stored in a database.
	Communications	GSM modem, radio modem or serial cable.
	'Smart' attributes	Automatic, continuous and autonomous operation: data can be accessed by authorized operators and used to generate warnings (through e-mail, etc.) or further analyzed for more information.
	Other	The 3DeMoN system is fully compatible with other SMARTEC products; results are stored in a standard SDB database and can be integrated with measurements from other sensors (e.g., SOFO, ADAM, etc.).

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☐ Multi-beam/girder system: ☒ Slab ☐ Truss member ☐ Arch element ☐ Other:	☐ Girder floor beam/diaphragm system	☐ Tee beam	☐ Box girder	☐ Channel beam	
	Secondary Element ☐ Connector and fastener: ☐ Bracing: ☐ Diaphragm ☐ Cover plate ☐ Stiffener ☐ Other:	☐ Riveted/bolted ☐ Cross	☐ Welded ☐ Lateral	☐ Pin & hanger ☐ Sway	☐ Splice	
	Bearing ☐ Fixed ☐ Expansion: ☐ Other:	☐ Sliding plate	☐ Roller	☐ Rocker	☐ Pin and link	☐ Elastomeric ☐ Pot ☐ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☐ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☐ Strand shoes 2. Movable bridge ☐ Electric brakes	☒ Main/secondary cable ☐ Cable bands ☐ Motors and power	☐ Cable anchorage ☐ Cable enclosures ☐ Operating machinery and equipment	☐ Anchor rod ☐ Other:	☐ Damping system ☐ Other:	
	Other:					

Monitoring Interest

☐ Crack/fracture	☐ Expansion/contraction	☒ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☐ Section loss	☒ Settlement	☒ Misalignment	☐ Connection failure or deficiencies
☒ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☒ Impact damage
☐ Debonding	☐ Erosion/scour	☐ Looseness and pounding	☐ Excessive joint closing/opening
☐ Corrosion	☐ Environmental	☐ Other:	

Measurement Metric

☐ Strain	☒ Deflection/displacement	☐ Acceleration/vibration	☐ Moisture/humidity level
☐ Temperature	☐ Magnetic field/flux	☐ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☐ Other:	

3. Cost		
Hardware	Sensor	SOFO sensor: $1,106~$2,282 per unit ($1.00 = CHF1.24). SOFO concrete setting sensor: $1,434 per unit. Inclinometer: $4,340~$4,565 per unit. Termocouples-temperature sensor: $165 per unit.
	Data acquisition system	SOFO V reading unit with DB software: $65,844 (1 channel) ~ $86,428 (12 channels). SOFO Bee with SDB software: $61,752 (12 chennels) ~ $71,548 (24 channels).
	Communication system	Variable.
	Data archiving system	Variable.
	Other	Junction box: $583 (1 to 10 sensors) ~ $1,091 (1 to 36 sensors). SOFO optical switch with 20 channels: $32,054.
Software	SOFO VIEW (graphic display and warning alert): $357/month ~ $2,852/license. SOFO PRO (real-time analysis and data interpretation): $388/month ~ $3,100/license. SOFO SPADS (curvature analysis): $876/month ~ $7,006/license. SOFO SDB (including PRO, VIEW and SPADS): $10,701/license.	
Labor	Installation	Variable.
	Use	SOFO traning course: $2,604. Support: $174 (engineer) ~ $217 (manager)/hour.
Other: Certificate of origin SOFO: $310. Accessories: variable (e.g., connecting cable, standard active part, junction cable, power supply, upgrade memory, other updates, etc).		

4. Limitations	
Life expectancy	20 years plus (depends on products)
Power	110/220V AC.
Environmental conditions	-30°C to 70°C.
Data storage/transfer/ processing	Data storage: SDB database.
Other: Maximum distance between station: 20 km.	

5. Implementation Needs	
Power source	AC/DC, or solar panel (can last 8 days without sun light).
Accessibility	Remote monitoring and control.
Technical expertise	Moderate training on system instalation and control. Training course is available.
Other:	

6. Availability

2 to 6 weeks.

7. On-Going or Completed Bridge Related Projects and References

Arsta Bridge, Sweden, 2003.
Soolshoi Moskvoretskiy Bridge, Russia, 2003.
Schladming Bridge, Austria, 2002.
Kameura Bridge, Japan, 2001.
Rio Puerco Bridge, New Mexico, 2000.
Colle Isarco Bridge, Italy, 1999.
Horsetail Fall Bridge, Oregon, 1998.
Many other bridge monitoring projects in many countries.

References:

- Lienhart, W., and Brunner, F.K. "Monitoring of Bridge Deformations Using Embedded Fiber Optical Sensors," Proceedings, 11th FIG Symposium on Deformation Measurements, Santorini, Greece, 2003.
- Vurpillot, S., Inaudi, D., and Ducret, J.M. "Bridge Monitoring by Fiber Optic Deformation Sensors: Design, Emplacement and Results," Smart Structures and Materials, Proceedings of SPIE, San Diego, CA, 1996.
- Numerous case studies and references are available on company website.

8. Notes

- Founded in 1996, SMARTEC SA is a developer, producer and distributor of measurement and structural health monitoring systems; the company's products range from sensors (fiber optic, GPS and conventional) and data acquisition systems to software for data management and analysis.
- SMARTEC offers support and training in the design, installation, use of monitoring systems, and the management and analysis of the resulting data.
- The 3DeMoN system is based on a network of GPS receivers installed on the object to be monitored and a base-station that oversees the operation of the whole system.
- Software allows the user to view and analyze all data with a single interface.

1. General Information

Description of Technology	Multiplexed Strain and Temperature Monitoring System (MuST) based on Fiber Bragg Grating (FBG) sensors technologies.		
Manufacturer and Contact information	SMARTEC Via Pobiette 11, CH-6928 Manno, Switzerland	www.smartec.ch Tel: +41 91 610 18 00 Fax: +41 91 610 18 01	
Features	Sensor type	FBG deformation sensors: possible to connect up to 5 full-range sensors; embeddable or mountable. FBG temperature sensors:capable of a maximum total of 100 measurement points.	
	Data acquisition, processing, and archiving	MuST FBG reading unit can carry out static and dynamic measurements; permanent instrumentation; High resolution and precision; water tight steel housing; modular design; automatic and remote control; compatible with all FBG sensors and SOFO softwares suite.	
	Communications	Data is transmitted to the PC running the SOFO SDB software via a standard Ethernet connection. Remote connection is possible via modem or wireless LAN.	
	'Smart' attributes	Real-time, continuous temperature and displacement monitoring with alarm triggering capability.	
	Other	Sensors immune or insensitive to electromagnetic fields, humidity, vibrations and corrosion. No calibration required. Waterproof.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☒ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☒ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☒ Main/secondary cable ☒ Cable anchorage ☒ Anchor rod ☒ Damping system ☒ Strand shoes ☒ Cable bands ☒ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☐ Crack/fracture	☒ Expansion/contraction	☐ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☐ Section loss	☐ Settlement	☐ Misalignment	☐ Connection failure or deficiencies
☒ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☐ Impact damage
☐ Debonding	☐ Erosion/scour	☐ Looseness and pounding	☐ Excessive joint closing/opening
☐ Corrosion	☒ Environmental	☐ Other:	

Measurement Metric

☒ Strain	☒ Deflection/displacement	☐ Acceleration/vibration	☐ Moisture/humidity level
☒ Temperature	☐ Magnetic field/flux	☐ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☐ Other:	

3. Cost		
Hardware	Sensor	SOFO sensor: $1,106~$2,282 per unit ($1.00 = CHF1.24). SOFO concrete setting sensor: $1,434 per unit. Inclinometer: $4,340~$4,565 per unit. Termocouples-temperature sensor: $165 per unit.
	Data acquisition system	SOFO V reading unit with DB software: $65,844 (1 channel) ~ $86,428 (12 channels). SOFO Bee with SDB software: $61,752 (12 chennels) ~ $71,548 (24 channels).
	Communication system	
	Data archiving system	
	Other	Junction box: $583 (1 to 10 sensors) ~ $1,091 (1 to 36 sensors).
Software	SOFO VIEW (graphic display and warning alert): $357/month ~ $2,852/license. SOFO PRO (real-time analysis and data interpretation): $388/month ~ $3,100/license. SOFO SPADS (curvature analysis): $876/month ~ $7,006/license. SOFO SDB (including PRO, VIEW and SPADS): $10,701/license.	
Labor	Installation	Variable.
	Use	SOFO traning course: $2,604. Support: $174 (engineer) ~ $217 (manager)/hour.
Other: Certificate of origin SOFO: $310. Accessories: variable (e.g., connecting cable, standard active part, junction cable, power supply, upgrade memory, other updates, etc).		

4. Limitations	
Life expectancy	20 years plus (depends on products).
Power	MuST FBG reading unit: 230V 50Hz/110V 60Hz AC Auto detect, 24V DC.
Environmental conditions	Sensors: -40°C to 80°C, maximum of -65°C to 300°C for temperature sensor. -20°C to 60°C (operating), 90% relative humidity (non-condensed).
Data storage/transfer/ processing	Measurement rate up to 512 FBGs on four fibers. A maximum scan rate up to 250 Hz over a 50 nm range.
Other:	

5. Implementation Needs	
Power source	Battery, AC/DC, or solar panel (can last 8 days without sun light).
Accessibility	Remote monitoring and control.
Technical expertise	Minimal training for system instalation and control. Training course is available.
Other: Minimum of Pentium II, 128MB RAM, 50MB hard disk, 800x600 display.	

6. Availability

2 to 6 weeks.
Some equipment available for rental.

7. On-Going or Completed Bridge Related Projects and References

Arsta Bridge, Sweden, 2003.
Soolshoi Moskvoretskiy Bridge, Russia, 2003.
Schladming Bridge, Austria, 2002.
Kameura Bridge, Japan, 2001.
Rio Puerco Bridge, New Mexico, 2000.
Colle Isarco Bridge, Italy, 1999.
Horsetail Fall Bridge, Oregon, 1998.
Many other bridge monitoring projects in many countries.

References:

- Lienhart, W., and Brunner, F.K. "Monitoring of Bridge Deformations Using Embedded Fiber Optical Sensors," Proceedings, 11th FIG Symposium on Deformation Measurements, Santorini, Greece, 2003.
- Vurpillot, S., Inaudi, D., and Ducret, J.M. "Bridge Monitoring by Fiber Optic Deformation Sensors: Design, Emplacement and Results," Smart Structures and Materials, Proceedings of SPIE, San Diego, CA, 1996.
- Numerous case studies and references are available on company website.

8. Notes

- Founded in 1996, SMARTEC SA is a developer, producer and distributor of measurement and structural health monitoring systems; the company's products range from sensors (fiber optic, GPS and conventional) and data acquisition systems to software for data management and analysis.
- SMARTEC offers support and training in the design, installation, use of monitoring systems, and the management and analysis of the resulting data.
- The MuST reading unit allows to simultaneously measure up to 4 sensor strings with up to 128 sensors per string; through the use of an optional integrated optical switch, it is possible to monitor up to 16 sensors strings sequentially (4 by 4).
- The reading unit is available in a ruggedized casing or in rack-mounted versions.
- The system is compatible with SOFO SDB software including SOFO SDB Pro, View, SPADS and Realtime.
- The MuST system is adapted for relatively small applications.

1. General Information

Description of Technology	Customized structure health monitoring system.	
Manufacturer and Contact information	Smart Structures LLC. 233 N. Garrard, Rantoul, IL 61866	www.smart-structures.com Tel: (217) 892-3333 Fax: (217) 893-8806
Features	Sensor type	Magnetoelastic (EM) stress sensors (stress and corrosion monitoring). Wireless sensors (strain, displacement, acceleration and temperature). Fiber optic displacement sensor (FODS).
	Data acquisition, processing, and archiving	A rack-mount UNIX-based PC, controlling multifunction data acquisition card and modem, and signal condition modules and anti-aliasing filters. Bridge monitoring system (BMS) software (web-based server application, password protected) capable of requency distribution, curvature, shear strain analysis, and traffic count.
	Communications	Direct wire connection, telephone line, LAN, Internet, wireless network, and other options upon request.
	'Smart' attributes	Continuous monitoring, real-time data access, alarm/warning system.
	Other	FODS control unit: up to 7 modules, each controlling two large motion sensors. Internet server optional.

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☒ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☐ Shaft	☒ Column/stem	☐ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☒ Main/secondary cable ☒ Cable anchorage ☒ Anchor rod ☒ Damping system ☒ Strand shoes ☒ Cable bands ☒ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☒ Crack/fracture	☒ Expansion/contraction	☒ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☐ Section loss	☐ Settlement	☐ Misalignment	☒ Connection failure or deficiencies
☒ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☒ Impact damage
☐ Debonding	☒ Erosion/scour	☐ Looseness and pounding	☒ Excessive joint closing/opening
☒ Corrosion	☐ Environmental	☒ Other: Cable force.	

Measurement Metric

☒ Strain	☒ Deflection/displacement	☒ Acceleration/vibration	☐ Moisture/humidity level
☒ Temperature	☒ Magnetic field/flux	☐ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☒ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☐ Other:	

3. Cost		
Hardware	Sensor	EM senosrs: $140~$2000 per unit. 4-channel module for EM sensor: $700~$900 per unit.
	Data acquisition system	Reading unit for EM sensor: $5000~$6500.
	Communication system	
	Data archiving system	
	Other	Customized monitoring system is priced based on specification and monitoring requirements.
Software		
Labor	Installation	
	Use	
Other: Additional cost for PC and other necessary instruments.		

4. Limitations	
Life expectancy	FOS: designed for 40-year lifetime.
Power	120V AC ±10% (power supply), 15W (power consumption) for FODS control unit.
Environmental conditions	-40°C to 70°C.
Data storage/transfer/ processing	Depends on products and specifications.
Other:	

5. Implementation Needs	
Power source	Battery, AC/DC, solar panel.
Accessibility	Direct access needed for sensor installation. Direct access or remote monitoring.
Technical expertise	Minimal training. Basic electronic and computer skills.
Other:	

6. Availability
Upon agreement.

7. On-Going or Completed Bridge Related Projects and References
Nanjing Bridge, China. Ashida Sawa Bridge, Japan. South Dakota Bridge. Jumagaya Dome, Japan.

8. Notes
• Smart Structures has developed and manufactured standard products and customized systems capable of monitoring all aspects of the structural health. • The company offers custom made products including EM sensors and other monitoring devices for any size of cables/strands. • Sensors and devices for rebar corrossion monitoring and for threaded fastener clamp load monitoring are currently under development.

1. General Information

Description of Technology	Portable, rugged data acquisition and analysis system.		
Manufacturer and Contact information	Somat Ltd. 702 West Killarney, Urbana, IL 61801	www.somat.com Tel: (217) 328-5359 Fax: (217) 328-6576	
Features	Sensor type	Somat's data acquisition system can be used with strain gages, accelerometers, pressure gages, load cells, tiltmeter, and temperature gages.	
	Data acquisition, processing, and archiving	eDAQ and SoMat2100 data acquisition system (compact, self-contained and rugged data acquisition and analysis system). On-site PC for data archiving and server. Software to enhance field testing and the data collection and visualization process.	
	Communications	Direct wire connection, phone line, Internet, RF or other wireless options.	
	'Smart' attributes	Capable of unattended monitoring, simultaneous sampling, on-line data analysis, real-time computation, and customized alerting.	
	Other	Data acquisition hardware can store the transducer data either as time histories, burst histories, rainflow, or time at level.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☒ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☒ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☒ Main/secondary cable ☒ Cable anchorage ☒ Anchor rod ☒ Damping system ☒ Strand shoes ☒ Cable bands ☒ Cable enclosures ☐ Other: 2. Movable bridge ☒ Electric brakes ☒ Motors and power ☒ Operating machinery and equipment ☒ Other: Track castings, rack.					
	Other:					

Monitoring Interest

☒ Crack/fracture	☐ Expansion/contraction	☐ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☐ Section loss	☐ Settlement	☐ Misalignment	☐ Connection failure or deficiencies
☐ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☒ Impact damage
☐ Debonding	☐ Erosion/scour	☐ Looseness and pounding	☐ Excessive joint closing/opening
☐ Corrosion	☐ Environmental	☐ Other:	

Measurement Metric

☒ Strain	☒ Deflection/displacement	☒ Acceleration/vibration	☐ Moisture/humidity level
☒ Temperature	☐ Magnetic field/flux	☐ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☐ Other:	

3. Cost		
Hardware	Sensor	
	Data acquisition system	eDAQ system: $10,000~$14,000. 2100 system: $11,300.
	Communication system	Variable, some included.
	Data archiving system	Variable, some included.
	Other	System price depends on number of channel, sensors to be measrued, power supply, etc.
Software	Test control software (TCE) comes standard with the base unit. InField: $1,500 (additional $750 for frequency option: FRF, Inverse FRF, etc). Ralative Damage Comparator: $750	
Labor	Installation	
	Use	
Other: Example for typical 8-channel eDAQ system ($13,540): CPU classic ($4,495), Low level board, 350 ohm strain gages, 8-channels ($6,295), 512MB Flash ($350), AC power supply ($150), InField software ($1,500) and relative damage comparator ($750). Example for typical 8-channel 2100 system ($11,310): Turbo processor ($1,095), Power/communications module ($1,090), Communications odule with clock, status ($695), 4MB CMOS extended memory ($695), 9x strain gage module ($4,4550), compact flash module with 32MB flash card ($995), 128MB flash card ($95), AC adapter for 2025 ($95), SoMat TCS for windows ($595), InField software ($1,500), and relative damage comparator ($750).		

4. Limitations	
Life expectancy	No official life expectancy.
Power	SoMat 2100: 11.5V to 18V DC. eDAQ: 12V to 18V DC.
Environmental conditions	SoMat 2100: -20°C to 70°C eDAQ: -20°C to 65°C
Data storage/transfer/ processing	Depends on products and specifications.
Other:	

5. Implementation Needs	
Power source	AC/DC.
Accessibility	Direct access or remote monitoring.
Technical expertise	Minimal training. Electronics skills.
Other: Control PC for modem, serial ports, and watchdog timer.	

6. Availability

6 to 8 weeks.

7. On-Going or Completed Bridge Related Projects and References

Michigan Street Rolling Bascule Bridge over Sturgeon Bay in Door County, Wisconsin.

References:

- Prine, D. "First Global Remote Bridge Monitoring System Insures Safe Operation of 65 Year Old Lift Bridge," Basic Industrial Research Laboratory, Northwestern University, Chicago, Illinois, (www.somat.com/applications/articles/bridge_monitoring.htm).
- Laman, J.A. "Small, Self-Contained Field Computer Helps Researchers Collect Accurate Load Data from Highway Bridges," Department of Civil and Environmental Engineering, University of Michigan, Ann Arbor, Michigan, (www.somat.com/applications/articles/bridge_loaddata.htm).

8. Notes

- Since 1982, SoMat has developed and supplied portable data acquisition systems and software for field and laboratory testing and analysis; clients include advanced research firms and Fortune 500 companies around the world.
- SoMat2100 is suitable for low power requirements whereas eDAQ would be better for larger channel count.
- Ananlysis software provides normal statistisal informaition and performs rainflow analysis.
- Relative damage comparator tool takes a time history, performs a rainflow analysis and compares to three different slopes of failure lines.
- 2100 system can go up to approximately 15 channels.
- eDAQ can go up to 64 channels.

1. General Information

Description of Technology	Smart Pebble: a passive sensor activated by radio frequency waves for monitoring the level of chloride ingress into concrete bridge decks.		
Manufacturer and Contact information	SRI International 333 Ravenswood Avenue, Menlo Park, CA 94025-3493	www.sri.com Tel: (650) 859-4771 Fax: (650) 859-4111	
Features	Sensor type	Smart Pebble (1.5 in. diameter wireless devices with a weight of a typical piece of the rock aggregate) contains a chloride sensor and utilizes a radio-frequency identification (RFID) chip that can be queried remotely. The sensor developes a voltage whose strength is determined by salt concentration.	
	Data acquisition, processing, and archiving	The sensors can be activated by a $1,000 bandheld or vehicle-mounted RF identification data logger that gathers the data as it passes over them. To collect the sensors readings, the reader emits a blast of radio energy and each radio query identifies an individual pebble.	
	Communications	Radio frequency.	
	'Smart' attributes		
	Other	The Smart Pebble is designed to remotely powered, thus precluding the need for any lifetime-limiting batteries, and it can monitor chloride ingress depths of as much as 4 in.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☐ Timber:	☐ Plank ☐ Other:	☐ Nailed laminated	☐ Glue-laminated	☐ Prestressed laminated	☐ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☐ Steel:	☐ Grid ☐ Other:	☐ Orthotropic	☐ Buckle plate	☐ Corrugated steel flooring	
	☐ FRP:					
Superstructure	*Primary Element* ☐ Multi-beam/girder system: ☒ Slab ☐ Truss member ☐ Arch element ☐ Other:	☐ Girder floor beam/diaphragm system	☐ Tee beam	☐ Box girder	☐ Channel beam	
	Secondary Element ☐ Connector and fastener: ☐ Bracing: ☐ Diaphragm ☐ Cover plate ☐ Stiffener ☐ Other:	☐ Riveted/bolted ☐ Cross	☐ Welded ☐ Lateral	☐ Pin & hanger ☐ Sway	☐ Splice	
	Bearing ☐ Fixed ☐ Expansion: ☐ Other:	☐ Sliding plate	☐ Roller	☐ Rocker	☐ Pin and link	☐ Elastomeric ☐ Pot ☐ Restraining
	Other:					
Substructure	☐ Abutment:	☐ Footing ☐ Other:	☐ Bridge seat	☐ Piles	☐ Wall (stem/back/wing)	
	☐ Pier/bent/extended pile:	☐ Pier cap ☐ Other:	☐ Shaft	☐ Column/stem	☐ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☐ Tower ☐ Main/secondary cable ☐ Cable anchorage ☐ Anchor rod ☐ Damping system ☐ Strand shoes ☐ Cable bands ☐ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☐ Crack/fracture	☐ Expansion/contraction	☐ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☐ Section loss	☐ Settlement	☐ Misalignment	☐ Connection failure or deficiencies
☐ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☐ Impact damage
☐ Debonding	☐ Erosion/scour	☐ Looseness and pounding	☐ Excessive joint closing/opening
☒ Corrosion	☐ Environmental	☐ Other:	

Measurement Metric

☐ Strain	☐ Deflection/displacement	☐ Acceleration/vibration	☐ Moisture/humidity level
☐ Temperature	☐ Magnetic field/flux	☒ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☐ Other:	

3. Cost		
Hardware	Sensor	Expected to cost less than $100 per sensor.
	Data acquisition system	
	Communication system	
	Data archiving system	
	Other	
Software		
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	
Power	
Environmental conditions	
Data storage/transfer/ processing	
Other:	

5. Implementation Needs	
Power source	
Accessibility	
Technical expertise	
Other:	

6. Availability

7. On-Going or Completed Bridge Related Projects and References

Caltrans is formulating plans for a long-term evaluation of Smart Pebble prototypes in both the lab and in selected bridge decks.

References:

- Watters, D.G., Jayaweera, P., Bahr, A.J., Huestis, D.L., Priyantha, N., Meline R., Reis, R., Parks, D. "Smart Pebble: Wireless Sensors for Structural Health Monitoring of Bridge Decks," Smart Structures and Materials 2003: Smart Systems and Nondestructive Evaluation for Civil Infrastructures. Proceedings of the SPIE, Vol. 5057, pp. 20-28, 2003.
- Watters, D.G., Jayaweera, P., Bahr, A.J., and Huestis, D.L. "Design and Performance of Wireless Sensors for Structural Health Monitoring," SRI International.

8. Notes

- The sensor is designed to be inserted in the bridge deck either during the construction (or refurbishment) or in a back-filled core hole.
- SRI is working on adding temperature compensation circuitry and integrating all the components into a rugged 1-inch-diameter package. SRI's goal is to demonstrate the effectiveness of Smart Pebbles in real bridge decks.
- SRI is seeking an industrial partner for further development or technology licensing to mass-produce the Smart Pebbles devices.

1. General Information

Description of Technology	SMART Rebar: a new built-in diagnostic technique to detect debond and yielding within steel-reinforced concrete structures.		
Manufacturer and Contact information	Smart Structures Research Center (SSRC) AIST Tsukuba Central 2, 1-1-1 Umezono, Tsukuba, Ibaraki, Japan	unit.aist.go.jp/smart/eg/ Tel: +81-29-861-3127 Fax: +81-29-861-3126	
Features	Sensor type	Piezoelectric sensors: a distributed array of piezoceramic sensors on the rebar sends and receives diagnostic signals; takes advantage of piezoelectic elements (converting electrical energy to and from mechanical energy).	
	Data acquisition, processing, and archiving	A portable computer (e.g., laptop) fully equipped with diagnostic hardware and software interfaces with the sensor network on the SMART rebars; this can be used during a routine inspection or following a disaster.	
	Communications		
	'Smart' attributes		
	Other	The hardware system is a distributed network of piezoceramic sensors built into rebars and a portable computer.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☐ Timber:	☐ Plank ☐ Other:	☐ Nailed laminated	☐ Glue-laminated	☐ Prestressed laminated	☐ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☐ Prestressed/post-tensioned			
	☐ Steel:	☐ Grid ☐ Other:	☐ Orthotropic	☐ Buckle plate	☐ Corrugated steel flooring	
	☐ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☐ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☐ Cover plate ☐ Stiffener ☐ Other:	☐ Riveted/bolted ☐ Cross	☐ Welded ☐ Lateral	☐ Pin & hanger ☐ Sway	☐ Splice	
	Bearing ☐ Fixed ☐ Expansion: ☐ Other:	☐ Sliding plate	☐ Roller	☐ Rocker	☐ Pin and link	☐ Elastomeric ☐ Pot ☐ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☒ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☐ Main/secondary cable ☐ Cable anchorage ☐ Anchor rod ☐ Damping system ☐ Strand shoes ☐ Cable bands ☐ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☐ Crack/fracture	☐ Expansion/contraction	☐ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☐ Section loss	☐ Settlement	☐ Misalignment	☐ Connection failure or deficiencies
☐ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☐ Impact damage
☒ Debonding	☐ Erosion/scour	☐ Looseness and pounding	☐ Excessive joint closing/opening
☐ Corrosion	☐ Environmental	☒ Other: Yielding.	

Measurement Metric

☐ Strain	☐ Deflection/displacement	☐ Acceleration/vibration	☐ Moisture/humidity level
☐ Temperature	☐ Magnetic field/flux	☒ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☐ Other:	

3. Cost		
Hardware	Sensor	
	Data acquisition system	
	Communication system	
	Data archiving system	
	Other	
Software		
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	
Power	
Environmental conditions	
Data storage/transfer/ processing	
Other:	

5. Implementation Needs	
Power source	
Accessibility	
Technical expertise	
Other:	

6. Availability

The design of the SMART rebar is currently undergoing extensive testing and development.

7. On-Going or Completed Bridge Related Projects and References

References:

- Chan, H.L., and Chang., F.K. 2002: "Design of SMART Rebar for Detecting Disbond in Steel Reinforced Concrete," Structural Health Monitoring ISIS 2002 Workshop, Winnipeg, Manitoba, Canada.
- Wu, F., and Chang, F.K., "A Built-in Active Diagnostic System for Civil Infrastructure Systems," Proceedings of SPIE, Smart Materials and Structures: Smart Systems for Bridges, Structures and Highways, Vol. 4330, pp 27-35, March 2001.
- Wang, C., Wu, F., and Chang, F.K. "Structural Health Monitoring from Fiber-reinforced composites to steel-reinforced concrete," Journal of Smart Materials and Structures, Vol. 10, No. 3, pp 548-552, June 2001.

8. Notes

- Yielding and bond deterioration in reinforced concrete beams can be indicated by a delay in time-of-flight and an increase in amplitude of the diagnostic wave.
- The sensors and clips can be prefabricated separately before being mechanically attached to the steel rebar.

1. General Information

Description of Technology	Remotely monitoring the health of major structural inventory.	
Manufacturer and Contact information	Strain Monitor Systems (SMS) Inc. 314 Ayito Road, Southeast,Vienna, VA 22180	www.strainmonitor.com Tel: (703) 938-1057 Fax: 703-938-1252

Features		
	Sensor type	Peak displacement sensors (SMG032, SMG034). Vibrating wires. Strain sensors (embeddable or mountable).
	Data acquisition, processing, and archiving	SMJ010 data acquisition module (sensor interrogator, digitizes analog outputs of up to nine SMS sensors). SML025 on-site laptop interface. SMM010 sensor intwork master unit (provides a communications link back to the SMS contral data collection facility.
	Communications	Direct wire connection, landline and cellular modem, Internet, or satellite.
	'Smart' attributes	
	Other	SMSP010 solar power supply (a photovoltaic power system designed to power a SMS remote monitoring network. SEIMENS solar M55 panels are used for long-term durability.

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☒ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☐ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☐ Main/secondary cable ☐ Cable anchorage ☐ Anchor rod ☐ Damping system ☐ Strand shoes ☐ Cable bands ☐ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☒ Crack/fracture ☐ Expansion/contraction ☒ Rotation/torsion ☐ Wear/spalling/scaling/delamination
☐ Section loss ☐ Settlement ☒ Misalignment ☐ Connection failure or deficiencies
☒ Deformation ☐ Wire breakage ☐ Mechanical/electrical malfunction ☒ Impact damage
☐ Debonding ☐ Erosion/scour ☐ Looseness and pounding ☐ Excessive joint closing/opening
☐ Corrosion ☐ Environmental ☐ Other:

Measurement Metric

☒ Strain ☒ Deflection/displacement ☒ Acceleration/vibration ☐ Moisture/humidity level
☒ Temperature ☐ Magnetic field/flux ☐ Electrical voltage/current ☐ Chemical composition
☐ Radar waves ☐ Acoustic waves ☐ Magnetic waves ☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☒ Wind speed/direction ☐ Other:

3. Cost		
Hardware	Sensor	
	Data acquisition system	
	Communication system	
	Data archiving system	
	Other	
Software		
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	No official life expectancy.
Power	12V DC (SML025). 12 to 20V DC (SMM010). 9 to 12V DC (SMJ010) Power output of SMSP010 (solar power supply): 14.2W at 12V DC continuous.
Environmental conditions	-40°C to 65°C (SMG sensors).
Data storage/transfer/ processing	
Other:	

5. Implementation Needs	
Power source	Battery, AC/DC, solar pannel.
Accessibility	Direct access needed for sensor installation. Remote monitoring and control.
Technical expertise	Minimal training. Basic electronics and computer skills.
Other:	

6. Availability

Upon agreement.

7. On-Going or Completed Bridge Related Projects and References

I-85 ramp over I-85, Fulton County, GA.
I-95 over South Altamaha River, Glynn/Mclntosh County, GA.
I-75 over CR397, Allatoona Lake, Bartow County, GA.
Court St. Bridge, Owego, NY.

References:

• Tominaga, M., Sumitro, S., Okamoto, T., Kato, Y., and Kurokawa, S. "Development of Monitoring Technology for Steel and Composite Structures," Keisoku Research Consultant, Co. (www.krcnet.co.jp/papers/pdf/International/Steel2001_sumitoro.pdf).
• Some case studies and references are available on company website.

8. Notes

• SMS provides custom-engineered products, systems and solutions that would lower the growing risks associated with aging infrastructure (buildings, bridges, dams, pipelines, stadiums, etc.); customers automatically receive objective, real-time information from their structures.
• Features of SMS's engineered systems include: measuring peak strain or displacement, and report only the significant information generated; providing wireless information transfer over the Internet to any location, on a real-time, as desired basis; system does not require continuous power supply.

1. General Information

Description of Technology	Load measurement and stress analysis (from simple, battery-powered static logging systems to fully automated structural health monitoring systems).		
Manufacturer and Contact information	Strainstall Ltd. 9-10 Mariners Way, Cowes, Isle of Wight PO31 8PD UK	www.strainstall.com Tel: +44(0)1983 203600 Fax: +44(0)1983 291335	
Features	Sensor type	Strain gage, accelerometer, displacement sensor, load cell, rotational potentiometer, temperature sensor, crackmeter, inclinometer, anemometer (wind speed sensor).	
	Data acquisition, processing, and archiving	PC based data acquisition system configured for unattended, selective dynamic data acquisition and analysis system with 32 data channel capacity (DART: dynamic analysis in real time - DART2 and DART X32).	
	Communications	Direct wire connection, modem, or Internet.	
	'Smart' attributes	Real-time, continuous, remote monitoring system capable of sending data to a password-protected website for review in user-friendly graphical forms.	
	Other	System can be set up locally by a portable PC and then connected to the master PC by the communication network.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☒ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☐ Rocker	☐ Pin and link	☐ Elastomeric ☐ Pot ☐ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☒ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☐ Main/secondary cable ☐ Cable anchorage ☐ Anchor rod ☐ Damping system ☐ Strand shoes ☐ Cable bands ☐ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☒ Crack/fracture	☒ Expansion/contraction	☒ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☒ Section loss	☐ Settlement	☒ Misalignment	☐ Connection failure or deficiencies
☒ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☒ Impact damage
☐ Debonding	☐ Erosion/scour	☐ Looseness and pounding	☐ Excessive joint closing/opening
☐ Corrosion	☒ Environmental	☒ Other: Overload.	

Measurement Metric

☒ Strain	☒ Deflection/displacement	☒ Acceleration/vibration	☒ Moisture/humidity level
☒ Temperature	☐ Magnetic field/flux	☐ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☒ Wind speed/direction	☒ Other: Load.	

3. Cost		
Hardware	Sensor	
	Data acquisition system	
	Communication system	
	Data archiving system	
	Other	
Software		
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	No official life expectancy.
Power	18/30V DC or 110/240V AC
Environmental conditions	-20°C to 50°C, up to 95% relative humidity (non-condensing).
Data storage/transfer/ processing	
Other:	

5. Implementation Needs	
Power source	AC/DC.
Accessibility	Direct access or remote monitoring.
Technical expertise	Basic electronics and computer skills.
Other:	

6. Availability

Upon agreement.

7. On-Going or Completed Bridge Related Projects and References

Forth Bridge, Scotland.
Penarth Road Bridge, UK.
Ynysforgan Viaduct, South Wales.
Hodson Footbridge, UK
Constantius Bridge, UK.
Jiangyin Yangtze River Highway Bridge, China.
Many other bridge monitoring projects in may countries.

8. Notes

- Since the 1960's, Strainstall has developed numerous systems to monitor physical and performance parameters such as load, stress, temperature, acceleration, pressure and displacement.
- The company offers custom engineered systems for specific appliations.
- In normal mode, summary data is downloaded periodically to the management workstation computer. Extra data is acquired and reported if an alarm condition is exceeded on any data channel.

1. General Information

Description of Technology	Comparative Vacuum Monitoring (CVM) system for in-situ, real-time monitoring of crack initiation and/or propagation; consisting of an inert sensor, a regulated vacuum source, and a fluid flow-measruing device.	
Manufacturer and Contact information	Structural Monitoring Systems (SMS) Ltd Unit 5 15 Walters Drive, Osborne Park WA 6017, Australia	www.smsystems.com.au Tel: +61 8 9204 4844 or (814) 234-4817 (US office)
Features	Sensor type	CVM sensors: polymers-based lightweight, inert, and passive and durable sensors; the most popular all-purpose polymer sensor is a Silicone combined with a pre-applied Silicone Pressure Sensitive Adhesive.
	Data acquisition, processing, and archiving	PM4: a self contained testing system and data logger; user can carries the PM4 unit to each test point; the shole inspection and data acquisition process is hands free other than connecting and disconnecting the system interface coupling. The data is automatically logged. Overall time is about 4 to 5 minutes.
	Communications	Direct wire connection.
	'Smart' attributes	
	Other	The system detects sub-1mm cracks in processed surfaces; measures the physical crack; operates on peened, painted and otherwise treated surfaces.

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☒ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☐ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☒ Main/secondary cable ☒ Cable anchorage ☒ Anchor rod ☒ Damping system ☒ Strand shoes ☒ Cable bands ☒ Cable enclosures ☐ Other: 2. Movable bridge ☒ Electric brakes ☒ Motors and power ☒ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☒ Crack/fracture	☐ Expansion/contraction	☐ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☐ Section loss	☐ Settlement	☐ Misalignment	☐ Connection failure or deficiencies
☐ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☐ Impact damage
☐ Debonding	☐ Erosion/scour	☐ Looseness and pounding	☐ Excessive joint closing/opening
☐ Corrosion	☐ Environmental	☒ Other: Continuity test with crack/no-crack.	

Measurement Metric

☐ Strain	☐ Deflection/displacement	☐ Acceleration/vibration	☐ Moisture/humidity level
☐ Temperature	☐ Magnetic field/flux	☐ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☒ Other: Differential pressure.	

3. Cost		
Hardware	Sensor	
	Data acquisition system	
	Communication system	
	Data archiving system	
	Other	
Software		
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	
Power	
Environmental conditions	
Data storage/transfer/ processing	
Other:	

5. Implementation Needs	
Power source	
Accessibility	
Technical expertise	
Other:	

6. Availability
Upon agreement.

7. On-Going or Completed Bridge Related Projects and References
Has not been used on bridge structure.

8. Notes
• SMS's CVM system has been developed and used for mainly for the aerospace industry. • CVM is a measure of the differential pressure between fine galleries containing a low vacuum alternating with galleries at atmosphere in a simple manifold. If no flaw is present, the vacuum will remain at a stable level. If a flaw develops, air will flow through the passage created from the atmosphere to the vacuum galleries. Sensors may either take the form of self-adhesive polymer "pads" or may form part of the component. A transducer measures the fluid flow between the galleries. • According to Keith McClennan from SMS (in the US), CVM can be well suited for monitoring bridge structures; Since it measures relative vacuum flow, it works on permeable materials such as concrete, in addition to steel and other materials. • SMS offers various design sensor shapes to suit customer requirements for structural components. Shape, size and crack sensitivity from 250 microns upwards can be designed and supplied to order. • Installing CVM sensors is simple and quick; the test surface is pre-cleaned and the sensor removed from its release liner case and laid on the test surface and rolled firmly down. The PTFE tubes are then inserted. In particularly harsh environments, sensors are over coated with specified polymer / resins to provide extra protection to the sensor and to the parent structure. • Sensors can also be embedded within the mass of a structure. Sensors can be embedded within bonded joints and lap joints to monitor for failure within the joint.

1. General Information

Description of Technology	Manufacturer of precision accelerometer, inertial, and VXI products.		
Manufacturer and Contact information	Summit Instruments, Inc. 2236 N Cleveland-Massillon Rd, Akron, OH 44333-1255	www.summitinstruments.com Tel: (330) 659-3312 Fax: (330) 659-3286	
Features	Sensor type	Uniaxial and triaxial accelerometer system: user-configurable acceleration measurement system containing an accelerometer, a temperature sensor, a signal processor, an IRIG-106 PCM encoder, a RS485 interface and three analog outputs in a small package.	
	Data acquisition, processing, and archiving	32 Channel D/A Converter with Configurable Closed-Loop Control VXI Card (C size): can be used for controlling either high current or high channel count applications; it allows the separation of the the high power devices from the precision instrumentation and control circuitry.	
	Communications		
	'Smart' attributes		
	Other	Instrument Configuration Utility (ICU) software: sensor configuration and output can be viewed for easy verification; real-time strip chart can simultaneously display all channels or a user-selected channel.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☐ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☐ Riveted/bolted ☒ Cross	☐ Welded ☒ Lateral	☐ Pin & hanger ☒ Sway	☐ Splice	
	Bearing ☐ Fixed ☐ Expansion: ☐ Other:	☐ Sliding plate	☐ Roller	☐ Rocker	☐ Pin and link	☐ Elastomeric ☐ Pot ☐ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☐ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☐ Strand shoes 2. Movable bridge ☐ Electric brakes	☐ Main/secondary cable ☐ Cable bands ☐ Motors and power	☐ Cable anchorage ☐ Cable enclosures ☐ Operating machinery and equipment	☐ Anchor rod ☐ Other:	☐ Damping system ☐ Other:	
	Other:					

Monitoring Interest

☒ Crack/fracture	☐ Expansion/contraction	☐ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☐ Section loss	☐ Settlement	☐ Misalignment	☐ Connection failure or deficiencies
☐ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☒ Impact damage
☐ Debonding	☐ Erosion/scour	☒ Looseness and pounding	☐ Excessive joint closing/opening
☐ Corrosion	☐ Environmental	☐ Other:	

Measurement Metric

☐ Strain	☐ Deflection/displacement	☒ Acceleration/vibration	☐ Moisture/humidity level
☒ Temperature	☐ Magnetic field/flux	☐ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☐ Other:	

3. Cost		
Hardware	Sensor	Uniaxial smart acclerometer system: $995 per unit. Triaxial smart acclerometer system: $1,295 per unit.
	Data acquisition system	32 Channel D/A converter with configurable closed-loop control: $5,395~ Diagnostic probe board for B and C size VXI systems: $495~
	Communication system	
	Data archiving system	
	Other	Accelerometer mounting adaptor: $45. PC interface adaptor: $120.
Software	Can be downloaded from the company's website.	
Labor	Installation	
	Use	
Other: 33% educational discount available.		

4. Limitations	
Life expectancy	No official life expectancy.
Power	Accelerometers: 8 to 30V DC.
Environmental conditions	Accelerometers: -40 to 85°C. Temperature sensor: -55 to 125°C.
Data storage/transfer/ processing	Accelerometer sensor scan rate: maximum of 42,500 Hz.
Other: Accelerometers: shock survival range from -500 to 500g (powered) or from -1,000 to 1000g (unpowered). The data acquisition rate is limited by the performance of the computer running ICU. Faster computers can process continuous data at 115K BAUD and above. CRC-16 error checking is used when communicating with instruments to ensure data integrity.	

5. Implementation Needs	
Power source	DC.
Accessibility	
Technical expertise	Manuals available on website. Technical support available on-line or by phone.
Other:	

6. Availability
Approximately 4 weeks.

7. On-Going or Completed Bridge Related Projects and References
Informaiton not available.

8. Notes
• Summit Instruments, Inc. was founded in 1987 and have provided test and measurement devices for various research applications.

1. General Information

Description of Technology	Supplier of various sensors and data acquisition systems.	
Manufacturer and Contact information	SuperLogics, Inc. 85 River Street, Waltham, MA 02453	www.superlogics.com Tel: (781) 893-1600 Fax: (781) 893-0600
Features	Sensor type	Strain sensor, temperature gage, accelerometer, and others.
	Data acquisition, processing, and archiving	USB-8516, 8518-S and 9350-SYS (high resolution, light weight data acquisition devices): all accept signals from various sensors. Compatable with Windows-based PCs and loptops. WINview software: ready-to-run data acquisition software for USB, LAN and wireless devices.
	Communications	Direct wire connection or Ethernet. Other wireless solutions available.
	'Smart' attributes	
	Other	Monitoring system can be customized to meet various requirements.

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber: ☒ Plank ☐ Other: ☒ Nailed laminated ☒ Glue-laminated ☒ Prestressed laminated ☒ Stressed timber	
	☒ Concrete: ☒ Reinforced ☐ Other: ☒ Prestressed/post-tensioned	
	☒ Steel: ☒ Grid ☐ Other: ☒ Orthotropic ☒ Buckle plate ☒ Corrugated steel flooring	
	☒ FRP:	
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Girder floor beam/diaphragm system ☒ Tee beam ☒ Box girder ☒ Channel beam ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	
	Secondary Element ☒ Connector and fastener: ☒ Riveted/bolted ☒ Welded ☒ Pin & hanger ☒ Splice ☒ Bracing: ☒ Cross ☒ Lateral ☒ Sway ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	
	Bearing ☒ Fixed ☒ Expansion: ☒ Sliding plate ☒ Roller ☒ Rocker ☒ Pin and link ☒ Elastomeric ☒ Pot ☒ Restraining ☐ Other:	
	Other:	
Substructure	☒ Abutment: ☒ Footing ☐ Other: ☒ Bridge seat ☒ Piles ☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile: ☒ Pier cap ☐ Other: ☒ Shaft ☒ Column/stem ☐ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☐ Main/secondary cable ☐ Cable anchorage ☐ Anchor rod ☐ Damping system ☐ Strand shoes ☐ Cable bands ☐ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:	
	Other:	

Monitoring Interest

☒ Crack/fracture ☐ Expansion/contraction ☐ Rotation/torsion ☐ Wear/spalling/scaling/delamination
☐ Section loss ☐ Settlement ☐ Misalignment ☐ Connection failure or deficiencies
☒ Deformation ☐ Wire breakage ☐ Mechanical/electrical malfunction ☒ Impact damage
☐ Debonding ☐ Erosion/scour ☐ Looseness and pounding ☐ Excessive joint closing/opening
☐ Corrosion ☐ Environmental ☐ Other:

Measurement Metric

☒ Strain ☒ Deflection/displacement ☒ Acceleration/vibration ☐ Moisture/humidity level
☒ Temperature ☐ Magnetic field/flux ☐ Electrical voltage/current ☐ Chemical composition
☐ Radar waves ☐ Acoustic waves ☐ Magnetic waves ☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☐ Wind speed/direction ☐ Other:

3. Cost		
Hardware	Sensor	Strain gage: $69-$225/unit. Accelerometer: $295-$1,495/unit. Temperature sensor: $44-$120/unit.
	Data acquisition system	USB-8516: $596/unit. 8518-S: $660/unit. 9350-SYS: $895/unit.
	Communication system	XW-900: $249/unit.
	Data archiving system	Variable.
	Other	Sensor price variable depending on model type.
Software	WINview CP 32: $349	
Labor	Installation	
	Use	
Other: Optional: strain gage module ($259), Single Port RS-232 Serial PCMCIA Card ($95), Single Port RS-232/422/485 Serial Device Server ($189), Strain gage bridge completion module ($69), 8 Channel Thermocouple or mV Input, 16-Bit, Data Acquisition Module ($199), Highly Regulated Excitation Source for Strain Gages and Transducers ($175), 4 Channel ICP Sensor/Accelerometer/Voltage Input Expander Unit $545), 8 Channel RTD Input Expander Unit with Gains of 1, 10, 100 ($725), 14 Channel Thermocouple and mV Input Portable Expander Unit ($745), etc.		

4. Limitations	
Life expectancy	No official life expectancy.
Power	9350-SYS: +5V: 20mA (typ), +15V: 30mA (typ), -15V: 30mA (typ). USB-8516 and 8518-S: 10 to 30V DC
Environmental conditions	-25 to 75°C for USB-8516 and 8518-S.
Data storage/transfer/ processing	
Other:	

5. Implementation Needs	
Power source	AC/DC.
Accessibility	Direct access or remote monitoring.
Technical expertise	Minimal. Basic electronics and computer skills.
Other:	

6. Availability
0 to 2 weeks.

7. On-Going or Completed Bridge Related Projects and References
Information is not available.

8. Notes
• SuperLogics, Inc. offers PCI, USB, PCMCIA, Serial, Ethernet and wireless solutions and a wide variety of complementary products such as sensors, data communications and industrial PCs; the company also offers software development environments as well as software services to meet the challenges of complex applications. • SuperLogics's products are not for a specific application, but rather the products can take signals from any type of transducers/sensor from any type of application; some products have been used on bridge monitoring projects but the company does not keep track of a database on types of applications.

1. General Information

Description of Technology	Civil engineering transducers and data loggers for measuring various physical quantities.		
Manufacturer and Contact information	Texas Measurements, Inc. P.O. Box 2618, College Station, TX 77841	www.straingage.com Tel: (979) 764-0442 Fax: (979) 696-2390	
Features	Sensor type	Displacement transducers (DP/PI). Acceleration transducers (ARF/ARE/ARH). Embedment strain gauges (KM). Reinforcing-bar meters (KSA/KSAT). Joint meter (KJ). Crack displacement transducers (KG). Temperature gauges (TK). Thermocouples (T/K).	
	Data acquisition, processing, and archiving	DRA-101C/107A: 10-channel, dynamic strainmeter intended for on-line measurement with a computer; self dignostic function for sensitivity, input and insulation. DRA-7610 dynamic measurement software for processing data and measuring dynamic phenomenon using up to ten DRA digital dynamic strainmeter (up to 100 channels).	
	Communications	Direct wire connection.	
	'Smart' attributes		
	Other	SDA-810C/830C: 8-channel, small and lightweight, carrier type dynamic strainmeter; automatic retrieval function of peak value of storage data wave form; computer control via RS-232C; suitable with SDA-7910 software.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☒ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☐ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☐ Main/secondary cable ☐ Cable anchorage ☐ Anchor rod ☐ Damping system ☐ Strand shoes ☐ Cable bands ☐ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☒ Crack/fracture ☒ Expansion/contraction ☒ Rotation/torsion ☐ Wear/spalling/scaling/delamination
☐ Section loss ☒ Settlement ☒ Misalignment ☐ Connection failure or deficiencies
☒ Deformation ☒ Wire breakage ☐ Mechanical/electrical malfunction ☐ Impact damage
☐ Debonding ☐ Erosion/scour ☐ Looseness and pounding ☐ Excessive joint closing/opening
☐ Corrosion ☐ Environmental ☐ Other:

Measurement Metric

☒ Strain ☒ Deflection/displacement ☒ Acceleration/vibration ☐ Moisture/humidity level
☒ Temperature ☐ Magnetic field/flux ☒ Electrical voltage/current ☐ Chemical composition
☐ Radar waves ☐ Acoustic waves ☐ Magnetic waves ☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☐ Wind speed/direction ☐ Other:

3. Cost		
Hardware	Sensor	DP: $985-$1,150. PI: $215. ARF: $482. ARE: $500. ARH: $760. KM: $253.50-$365. KSA: $465-$645. KSAT: $496-$680. KJ: $565-$725. KG: $359-$625. KB: $1,420. TK-F: $185.50. T:$21-$24.25. K: $22.25-$23.
	Data acquisition system	DRA-101C: $24,490 + options; extension memory of 64K ($222.5), 192K ($324), 448K ($425). Thermocouple unit TCA-10A (10 channels): $15,560. Cycle counter interface CCI-1A: $1,415. DRA-107A: $18,380. SDA: $12,480 (810C) and $13,725 (830C) + options; printer TDP-544B ($2,125), DCC-544 ($645), RS-232C cable CR-57 ($65.5).
	Communication system	
	Data archiving system	
	Other	
Software	DRA-7610: $3,060. SDA-7910: $3,060.	
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	No official life expectancy.
Power	DRA-101C: 90 to 250V AC, 50/60 Hz 120VA max. SDA-810C: 85 to 132V or 170 to 262V AC, 50/60 Hz 25VA max; 10.5 to 30V DC 1.4A max. SDA-830C: 85 to 132V or 170 to 262V AC, 50/60 Hz 35VA max; 10.5 to 30V DC 2.3A max.
Environmental conditions	0 t o 80°C (DP); 0 to 40°C (PI, ARF, ARE, and ARH); -20 to 60°C (KG and KB); -20 to 80°C (KM, KSA, KJ and TK).
Data storage/transfer/ processing	SDA-810C/830C: measuring range of ±25,000x10^{-6} strain; frequency response of 2.5 kHz (SDA-810C) and 10 kHz (SDA-830C); computer control via RS-232C.
Other:	

5. Implementation Needs	
Power source	AC/DC.
Accessibility	Direct access for sensor installation and data acquisition.
Technical expertise	Minimal. Basic electronics skills. Manual included with purchase.
Other:	

6. Availability

2 to 3 weeks for transducers and approximately 4 weeks for data collection system and software.

7. On-Going or Completed Bridge Related Projects and References

Many bridge monitoring projects (detail information not available from Texas Measurements, Inc.).

8. Notes

• Texas Measurements, Inc. is the US and Mexico representative for TML Products (www.tokyosokki.co.jp).

1. General Information

Description of Technology	Load cells and signal conditioning products.		
Manufacturer and Contact information	Transducer Techniques, Inc. 42480 Rio Nedo, Temecula, CA 92590	www.transducertechniques.com Tel: (800) 344-3965 or (951) 719-3965 Fax: (951) 719-3900	
Features	Sensor type	Load cells: electro-mechanical transducers that translate force or weight into voltage; all transducer sensing elements incorporate bonded foil strain gages wired in a full wheatstone bridge configuration.	
	Data acquisition, processing, and archiving	Data acquisition system: 16 channels; 12 bit resolution; 2 output analog PCI, USB, PCMCIA, or Firewire Bus depending on types. Software: 16 channel data logging software, LabView base package, and LabView full development system.	
	Communications	Direct wire connection.	
	'Smart' attributes		
	Other	Load cell digital displays: portable, handheld, peak capture display; intelligent panel mount meter amplifier/conditioner; high speed micro processor ditital panel mount meter; 5-channel amplifier/conditioner.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☒ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☒ Riveted/bolted ☒ Cross	☒ Welded ☒ Lateral	☒ Pin & hanger ☒ Sway	☒ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☐ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☐ Main/secondary cable ☐ Cable anchorage ☐ Anchor rod ☒ Damping system ☐ Strand shoes ☐ Cable bands ☐ Cable enclosures ☐ Other: 2. Movable bridge ☒ Electric brakes ☒ Motors and power ☒ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☐ Crack/fracture ☒ Expansion/contraction ☒ Rotation/torsion ☐ Wear/spalling/scaling/delamination
☐ Section loss ☒ Settlement ☒ Misalignment ☐ Connection failure or deficiencies
☐ Deformation ☐ Wire breakage ☒ Mechanical/electrical malfunction ☒ Impact damage
☐ Debonding ☐ Erosion/scour ☐ Looseness and pounding ☒ Excessive joint closing/opening
☐ Corrosion ☐ Environmental ☒ Other: Creep effect.

Measurement Metric

☒ Strain ☐ Deflection/displacement ☐ Acceleration/vibration ☐ Moisture/humidity level
☐ Temperature ☐ Magnetic field/flux ☒ Electrical voltage/current ☐ Chemical composition
☐ Radar waves ☐ Acoustic waves ☐ Magnetic waves ☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☐ Wind speed/direction ☐ Other:

3. Cost		
Hardware	Sensor	Beam load cells: $85~$310 per unit. Other load cells/force sensors: $345~$795 per unit.
	Data acquisition system	DAQ PCI : $1,425 (12 bit resolution) ~ $1,625 (16 bit resolution). DAQ PCMCIA: $1,625 (12 bit resolution) ~ $1,825 (16 bit resolution). DAQ USB: $2,025. DAQ Firewire Bus: $3,725.
	Communication system	
	Data archiving system	
	Other	DAQ signal conditioning: $245 (16 channel signal conditioning box), $295 (dual channel strain gauge module).
Software	DAQ-DLS16 (16-channel data logging software): $195. LabView base package: $995. LabView full development system: $1,995.	
Labor	Installation	
	Use	
Other: DAQ cables: $95.		

4. Limitations	
Life expectancy	No official life expectancy.
Power	Power: 4 to 15V DC or 115 VAC 10% 60 Hz 3 Watts
Environmental conditions	0 to 50°C
Data storage/transfer/ processing	Windows 2000/ME/NT.
Other:	

5. Implementation Needs	
Power source	AC, DC.
Accessibility	Direct access for data acquisition.
Technical expertise	Basic electronics skills. Manuals for each device available on website. Application assistance available through phone.
Other:	

6. Availability
1 to 4 weeks.

7. On-Going or Completed Bridge Related Projects and References
Information not available.

8. Notes
• Established in 1979, Transducer Techniques Inc. designs and manufactures a line of load cells, torque sensors, special purpose transducers and related instrumentation. • Some of data acquisition systems and software are manufactured by National Instruments (www.ni.com).

1. General Information

Description of Technology	Bridge foundation scour monitoring research performed by the Field Systems and Construction Automation Laboratory (FSCAL) at the University of Texas - Austin.		
Manufacturer and Contact information	Design Analysis Associates, Inc. 75 West 100 South, Logan, UT 84321	www.waterlog.com Tel: (435) 753-2212 Fax: (435) 753-7669	
Features	Sensor type	Sonar system, water-level and flow velocity sensors, atmospheric sensors (air temperature, wind speed, precipitation, etc.).	
	Data acquisition, processing, and archiving	Standard data logging system, remote processing unit, remote terminals/workstations.	
	Communications	Direct wire connection, celluar, radio, or satellite.	
	'Smart' attributes		
	Other	The system can be built by selecting individual components from various manufactures of specialty equipment, or can be purchased as a complete system.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☐ Timber: ☐ Plank ☐ Nailed laminated ☐ Glue-laminated ☐ Prestressed laminated ☐ Stressed timber ☐ Other:	
	☐ Concrete: ☐ Reinforced ☐ Prestressed/post-tensioned ☐ Other:	
	☐ Steel: ☐ Grid ☐ Orthotropic ☐ Buckle plate ☐ Corrugated steel flooring ☐ Other:	
	☐ FRP:	
Superstructure	*Primary Element* ☐ Multi-beam/girder system: ☐ Girder floor beam/diaphragm system ☐ Tee beam ☐ Box girder ☐ Channel beam ☐ Slab ☐ Truss member ☐ Arch element ☐ Other:	
	Secondary Element ☐ Connector and fastener: ☐ Riveted/bolted ☐ Welded ☐ Pin & hanger ☐ Splice ☐ Bracing: ☐ Cross ☐ Lateral ☐ Sway ☐ Diaphragm ☐ Cover plate ☐ Stiffener ☐ Other:	
	Bearing ☐ Fixed ☐ Expansion: ☐ Sliding plate ☐ Roller ☐ Rocker ☐ Pin and link ☐ Elastomeric ☐ Pot ☐ Restraining ☐ Other:	
	Other:	
Substructure	☒ Abutment: ☐ Footing ☐ Bridge seat ☒ Piles ☐ Wall (stem/back/wing) ☒ Other: members subjected to scour.	
	☒ Pier/bent/extended pile: ☐ Pier cap ☐ Shaft ☒ Column/stem ☒ Submerged pile/pile cap/footing ☒ Other: members subjected to scour.	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☐ Tower ☐ Main/secondary cable ☐ Cable anchorage ☐ Anchor rod ☐ Damping system ☐ Strand shoes ☐ Cable bands ☐ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:	
	Other:	

Monitoring Interest

☐ Crack/fracture ☐ Expansion/contraction ☐ Rotation/torsion ☐ Wear/spalling/scaling/delamination
☐ Section loss ☐ Settlement ☐ Misalignment ☐ Connection failure or deficiencies
☐ Deformation ☐ Wire breakage ☐ Mechanical/electrical malfunction ☐ Impact damage
☐ Debonding ☒ Erosion/scour ☐ Looseness and pounding ☐ Excessive joint closing/opening
☐ Corrosion ☒ Environmental ☐ Other:

Measurement Metric

☐ Strain ☐ Deflection/displacement ☐ Acceleration/vibration ☒ Moisture/humidity level
☒ Temperature ☐ Magnetic field/flux ☐ Electrical voltage/current ☐ Chemical composition
☐ Radar waves ☐ Acoustic waves ☐ Magnetic waves ☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☒ Wind speed/direction ☒ Other: Sonar waves.

3. Cost		
Hardware	Sensor	
	Data acquisition system	Approximately $2,000.
	Communication system	
	Data archiving system	
	Other	
Software		
Labor	Installation	
	Use	Approximately $2,000~$2,500 per year (25% of a system cost).
Other: Approximately $8,000~$10,000 for a typical scour monitoring system.		

4. Limitations	
Life expectancy	
Power	
Environmental conditions	
Data storage/transfer/ processing	
Other:	

5. Implementation Needs	
Power source	Battery, AC/DC, solar panel.
Accessibility	Direct access or unattended remote monitoring.
Technical expertise	Moderate training on system installation and control.
Other:	

6. Availability

Upon agreement.

7. On-Going or Completed Bridge Related Projects and References

US Hwy 380 Bridge, Haskell County, Texas.
US Hwy 59 Bridges in Fort Bend County and Polk County, Texas.
US Hwy 90 Bridge, Liberty County, Texas.

References:

- Haas, C., Weissmann, J., and Groll, T. "Remote Bridge Scour Monitoring: A Prioritization and Implementation Guideline," Texas DOT Report7-3970, Center for Transportation Research, University of Texas at Austin, April 1999.
- Groll, T., Haas, C., and Weissmann, J. "Bridge Scour Prioritization Model," ASCE Journal of Trasportation Engineering, Spring 1999.

8. Notes

The research performed at the University of Texas was intended to:
- Evaluate existing scour monitoring systems for connectivity to telemetry devices;
- Field test candidate systems for reliability and maintainability;
- Design a system for monitoring bridge scour from field offices and traffic control centers;
- Prepare a statewide implementation plan.

1. General Information

Description of Technology	Corrosion monitoring of steel reinforced concrete structures using embedded instrumentation: long term corrosion monitoring including linear polarization resistance (LPR), open circuit potential (OCP), resistivity, chloride ion concentration (Cl-) and temperature.	
Manufacturer and Contact information	Virginia Technologies, Inc. (VTI) 2015 Ivy Road, Suite 423, Charlottesville, VA 22903	www.vatechnologies.com Tel: (434) 970-2200 Fax: (434) 817-6170
Features	Sensor type	ECI-1 (self-contained instrument including electrodes, electronics and a digital network interface).
	Data acquisition, processing, and archiving	ECI-1 is compatible with SDI-12 dataloggers and accessories. Datalogger is located external to the structure in an environmentally protected enclosure such as a NEMA-4 box. Datalogger connects to a multi-drop serial communications network.
	Communications	Wireless communication provided via an external cellular transceiver.
	'Smart' attributes	Continuous corrosion monitoring with alerting capability.
	Other	ECI-1 Enclosure is mounted in place using 4 pieces of #3 re-bar. These pieces of re-bar are wired to the support members of the structure and the ECI-1 becomes a permanent part of the structure after the concrete is set in place.

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☐ Timber:	☐ Plank ☐ Nailed laminated ☐ Glue-laminated ☐ Prestressed laminated ☐ Stressed timber ☐ Other:
	☒ Concrete:	☒ Reinforced ☒ Prestressed/post-tensioned ☐ Other:
	☐ Steel:	☐ Grid ☐ Orthotropic ☐ Buckle plate ☐ Corrugated steel flooring ☐ Other:
	☐ FRP:	
Superstructure	*Primary Element*	☐ Multi-beam/girder system: ☐ Girder floor beam/diaphragm system ☐ Tee beam ☐ Box girder ☐ Channel beam ☒ Slab ☐ Truss member ☐ Arch element ☐ Other:
	Secondary Element	☐ Connector and fastener: ☐ Riveted/bolted ☐ Welded ☐ Pin & hanger ☐ Splice ☐ Bracing: ☐ Cross ☐ Lateral ☐ Sway ☐ Diaphragm ☐ Cover plate ☐ Stiffener ☐ Other:
	Bearing	☐ Fixed ☐ Expansion: ☐ Sliding plate ☐ Roller ☐ Rocker ☐ Pin and link ☐ Elastomeric ☐ Pot ☐ Restraining ☐ Other:
	Other:	
Substructure	☒ Abutment:	☒ Footing ☒ Bridge seat ☐ Piles ☒ Wall (stem/back/wing) ☐ Other:
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Shaft ☒ Column/stem ☐ Submerged pile/pile cap/footing ☐ Other:
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)*	1. Cable-supported bridge ☐ Tower ☐ Main/secondary cable ☐ Cable anchorage ☐ Anchor rod ☐ Damping system ☐ Strand shoes ☐ Cable bands ☐ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:
	Other:	

Monitoring Interest

☐ Crack/fracture ☐ Expansion/contraction ☐ Rotation/torsion ☐ Wear/spalling/scaling/delamination
☐ Section loss ☐ Settlement ☐ Misalignment ☐ Connection failure or deficiencies
☐ Deformation ☐ Wire breakage ☐ Mechanical/electrical malfunction ☐ Impact damage
☐ Debonding ☐ Erosion/scour ☐ Looseness and pounding ☐ Excessive joint closing/opening
☒ Corrosion ☐ Environmental ☐ Other:

Measurement Metric

☐ Strain ☐ Deflection/displacement ☐ Acceleration/vibration ☒ Moisture/humidity level
☒ Temperature ☐ Magnetic field/flux ☒ Electrical voltage/current ☒ Chemical composition
☐ Radar waves ☐ Acoustic waves ☐ Magnetic waves ☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☐ Wind speed/direction ☐ Other:

3. Cost		
Hardware	Sensor	$1,195 per unit
	Data acquisition system	
	Communication system	
	Data archiving system	
	Other	
Software	Free.	
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	7 to 10 years conservatively. 20 to 30 years of expected life time.
Power	Inactive: 1.5 mAmps @ 12V. Active: 4.5 mAmps @ 12V.
Environmental conditions	-40°C to 70°C.
Data storage/transfer/ processing	
Other:	

5. Implementation Needs	
Power source	System can be powered using local electrical power lines, optional solar collector and rechargeable battery.
Accessibility	Sensors need to be embedded.
Technical expertise	Minimal training.
Other:	

6. Availability

30 days for 1-10 units, 60 days for larger amounts.

7. On-Going or Completed Bridge Related Projects and References

Route 29 bypass Bridge, Pleasant Valley Bridge, VA.
Central Expressway (CTE) Bridge, Singapore.
Other bridges in China.

References:

• "Monitor Warns of Bridge Corrosion," Better Bridges, Better Roads, August 2003 pp. 88 - 90.
• "Embedded Miniature Sensors Detect Chloride in Bridge Decks," Civil Engineering, June 2003 pp. 42-43.
• "The Bridge Battle," Bridge Builder, December, 2002 pp. 14-18.

• Some references are available on company website.

8. Notes

• VTI is an electronic instrumentation company with activities in research, development and manufacturing.
• The instruments communicate with each other and an external datalogger using a digital protocol which is highly resistant to nearby EMI sources.
• The molded plastic enclosure gives moisture and chemical protection to the instrument's electronics while providing a rigid base for the electrodes.
• Optimally, one instrument should be embedded for every 100 ft^2; a small number of instruments may be used and positioned at locations particularly prone to corrosion such as areas where water or road salts accumulate or at areas of greatest concern for corrosion that may be inaccessible to traditional probes after construction.
• No calibration needed after installation.
• Each network connection can be up to 200 ft in length.
• VTI has partnered with Campbell Scientific to provide a complete 'turn key' solution including instrument, software and all components external to the structure.

1. General Information

Description of Technology	Bridge Monitoring System (BRIMOS): monitoring and inspection system is based on the analysis of the dynamic characteristic of structures.		
Manufacturer and Contact information	Vienna Consulting Engineers (VCE) Hadikgasse 60, 1140 Vienna, Austria	www.vce.at Tel: +43 1 897 53 39 Fax: +43 1 893 86 71	
Features	Sensor type	Accelerometers (Kistler sensor or EPI sensor), displacement sensors, piezoelectric sensors, other sensors for dynamic measurements.	
	Data acquisition, processing, and archiving	BRIMOS recorder (data acquisition equipped with internal 3-dimensional Forced Balanced Accelerometer). BRIREC software (developed for Microsoft Windows) provides quick and easy data transfer to a monitoring station and provides dynamic characteristic of structure.	
	Communications	Direct wire connect, or Internet network.	
	'Smart' attributes	Automatic warning system for critical conditions	
	Other	BRIMOS-Recorder(designed as 'all-in-one' equipment): vibration signal is measured in three dimensions with high precision and is saved on the internal data loggers for further assessment.	

2. Applicability

Bridge Type

☐ Slab ☐ Girder/Deck ☐ Truss ☐ Arch
☐ Rigid Frame ☒ Suspension ☒ Cable-stayed ☐ Vertical lift
☐ Swing ☐ Bascule ☒ Other: No limitation but mainly Cable-supported bridge type.

Bridge Component

Deck	☐ Timber: ☐ Plank ☐ Nailed laminated ☐ Glue-laminated ☐ Prestressed laminated ☐ Stressed timber ☐ Other:	
	☒ Concrete: ☒ Reinforced ☒ Prestressed/post-tensioned ☐ Other:	
	☐ Steel: ☐ Grid ☐ Orthotropic ☐ Buckle plate ☐ Corrugated steel flooring ☐ Other:	
	☐ FRP:	
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Girder floor beam/diaphragm system ☒ Tee beam ☒ Box girder ☒ Channel beam ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	
	Secondary Element ☒ Connector and fastener: ☒ Riveted/bolted ☒ Welded ☒ Pin & hanger ☒ Splice ☒ Bracing: ☐ Cross ☐ Lateral ☐ Sway ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	
	Bearing ☐ Fixed ☐ Expansion: ☐ Sliding plate ☐ Roller ☐ Rocker ☐ Pin and link ☐ Elastomeric ☐ Pot ☐ Restraining ☐ Other:	
	Other:	
Substructure	☐ Abutment: ☐ Footing ☐ Bridge seat ☐ Piles ☐ Wall (stem/back/wing) ☐ Other:	
	☒ Pier/bent/extended pile: ☒ Pier cap ☒ Shaft ☒ Column/stem ☐ Submerged pile/pile cap/footing ☐ Other:	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☒ Main/secondary cable ☒ Cable anchorage ☐ Anchor rod ☐ Damping system ☐ Strand shoes ☒ Cable bands ☐ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:	
	Other:	

Monitoring Interest

☒ Crack/fracture ☐ Expansion/contraction ☒ Rotation/torsion ☒ Wear/spalling/scaling/delamination
☒ Section loss ☐ Settlement ☐ Misalignment ☒ Connection failure or deficiencies
☒ Deformation ☒ Wire breakage ☐ Mechanical/electrical malfunction ☒ Impact damage
☐ Debonding ☐ Erosion/scour ☐ Looseness and pounding ☐ Excessive joint closing/opening
☐ Corrosion ☒ Environmental ☐ Other:

Measurement Metric

☒ Strain ☒ Deflection/displacement ☒ Acceleration/vibration ☐ Moisture/humidity level
☒ Temperature ☐ Magnetic field/flux ☐ Electrical voltage/current ☐ Chemical composition
☐ Radar waves ☒ Acoustic waves ☐ Magnetic waves ☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☒ Wind speed/direction ☐ Other:

3. Cost		
Hardware	Sensor	Temperature sensor: € 420 ($508, for €1 = $1.21). Kistler sensor (including 20m cable and strap): € 3,000 ($3,630). EPI sensor (including 50m cable and plate for levelling): € 4,000 ($4,840).
	Data acquisition system	BRIMOS-Recorder 4 channels (including battery charger and BRIREC software: €10,880 ($13,165). BRIMOS-Recorder 7 channels (including battery charger and BRIREC software: €12,880 ($15,584).
	Communication system	Variable.
	Data archiving system	Variable.
	Other	Additional PC (price variable).
Software	BRIREC finishing software: included. BRIMOS evaluation software:€ 2,900 ($3,509) for 1 licence, €1,900 ($2,299) for 2-10 licence, €1,000 ($1,210) for > 10 licence.	
Labor	Installation	Variable depending on size of project.
	Use	Minimal.

Other: Service cost for monitoring project varies but typically four categories in terms of monitoring tasks (referring to standard bridge of 300m).
Category 0: ~ € 8,500 ($10,285) - General analysis of structure. Ambient acceleration measurement. Short in-situ evaluation, plausibility check, and report.
Category I: ~ €13,000 ($15,730) - FEM model. Detailed evaluation of data. Report (finding, required measures, recommendations). Damage scenario. Ambient acceleration measurement of stay cables and external tendons.
Category II: ~ € 55,000 ($66,550) - Instrumentation of piers and foundations. Periodic verifications. Comparison of basic measurement. Instrumentation of local areas (individual cross-sentions, piers, special components like construction joints).
Category III: ~ € 145,000 ($175,450) - Exmination of structural components. Installation, establishment of a connection for remote control and maintenance of system. Long-term assessment, Video monitoring. Selection of criteria for possible trigger control. Establishment of an automatic warning system for critical conditions.

4. Limitations	
Life expectancy	2 year guarantee and much longer life expectancy.
Power	12V DC or 110/230V AC
Environmental conditions	-20°C to 60°C, up to 95% at 50°C relative humidity (non-condensing).
Data storage/transfer/ processing	
Other:	

5. Implementation Needs	
Power source	AC/DC, solar panel.
Accessibility	Direct access or remote monitoring and control.
Technical expertise	Simple trainning on equipment. Basic computer skills and knowledge on dynamics.
Other:	

6. Availability

Approximately 4 weeks (for BRIMOS-Recorder 4 channels) to 10 weeks (for BRIMOS-Recorder 7 channels); Upon request otherwise (e.g., customized products and monitoring services, etc.); System update is available as needed.

7. On-Going or Completed Bridge Related Projects and References

Danube Bridge, Donaustadt Bridge, Spittelau Bridge, Tulln Bridge,Hainburg Bridge, Vils Bridge, Voest Bridge, Hall West Bridge, Austria.
Gi-Lu bridge, Kao Ping Hsi bridge, Taiwan.
Olympic Grand bridge, Korea.
Ludwigshafen bridge, Germany.

References:

- Herman Van der Auweraer, and Bart Peeters. "Smart Processing of Data from Permanent Monitoring Systems: Innovations and Needs," Presentation at the 5th SAMCo Workshop, January 26-27, 2004, (www.samco.org/download/ws5/auweraer.pdf).
- Wenzel, H. "On the Performance and Durability of Stay Cables," Vienna Consulting Engineers.
- Numerous case studies and references are availble on company website.

8. Notes

- Since the formation in 1980, VCE has been involved with major operations in Austria, Taiwan, Korea, Eastern Europe, the Middle East and Africa.
- BRIMOS system enables the assessment of the susceptibility of cables with regard to the two most frequent cases of cable vibrations: galloping at higher wind speeds and wind-rain-vibration at lower wind speeds.
- Other features and capabilities of BRIMOS include: Assessment of current condition of structure; Maintenance and rehabilitation planning; Traffic analysis; Life cycle predictions; Environmental and seismic assessment.

1. General Information

Description of Technology	Corrosion monitoring of reinforcing bar and other steel components: onset of corrosion, cessation of corrosion, and intensity of corrosion growth.		
Manufacturer and Contact information	VETEK Systems Corporation 6 Oak Road, Elkton, MD 21921	www.veteksystems.com Tel: (410) 398-7131 Fax: (410) 398-0312	
Features	Sensor type	V2000 electrode: a solid silver-silver chloride wire electrode wrapped in a permeable, non-conducting PVC covering. Corrosion Penetration Rate Monitoring (CPMP) system: monitors for the rate of penetration of corrosion conditions from the surface into a concrete structure.	
	Data acquisition, processing, and archiving	Commercially available hand-held volt meters: can measure one electrode/sensor. Standard data logger with CMS measurebox and connecting module: can measure up to 6x16 electrodes. System can be setup to store data to a PC either automatically or by mannual input.	
	Communications	Direct wire connection.	
	'Smart' attributes		
	Other	TDR cable: used to locate corrosion sites, when their existence is indicated by the output of the V2000 cable on long cables or structural steel elements.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☐ Timber:	☐ Plank ☐ Other:	☐ Nailed laminated	☐ Glue-laminated	☐ Prestressed laminated	☐ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☐ Steel:	☐ Grid ☐ Other:	☐ Orthotropic	☐ Buckle plate	☐ Corrugated steel flooring	
	☐ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☐ Connector and fastener: ☐ Bracing: ☐ Diaphragm ☐ Cover plate ☐ Stiffener ☐ Other:	☐ Riveted/bolted ☐ Cross	☐ Welded ☐ Lateral	☐ Pin & hanger ☐ Sway	☐ Splice	
	Bearing ☐ Fixed ☐ Expansion: ☐ Other:	☐ Sliding plate	☐ Roller	☐ Rocker	☐ Pin and link	☐ Elastomeric ☐ Pot ☐ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☒ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☒ Main/secondary cable ☐ Cable anchorage ☒ Anchor rod ☐ Damping system ☒ Strand shoes ☐ Cable bands ☐ Cable enclosures ☒ Other: Tensioning strands. 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☐ Crack/fracture	☐ Expansion/contraction	☐ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☐ Section loss	☐ Settlement	☐ Misalignment	☐ Connection failure or deficiencies
☐ Deformation	☐ Wire breakage	☐ Mechanical/electrical malfunction	☐ Impact damage
☐ Debonding	☐ Erosion/scour	☐ Looseness and pounding	☐ Excessive joint closing/opening
☒ Corrosion	☐ Environmental	☐ Other:	

Measurement Metric

☐ Strain	☐ Deflection/displacement	☐ Acceleration/vibration	☐ Moisture/humidity level
☐ Temperature	☐ Magnetic field/flux	☒ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☐ Other:	

3. Cost		
Hardware	Sensor	V2000 monitoring cable/meter: $22 (<100 m); $19.20 (between 100 m to 1,000 m); $17.50 (>1,000 m). Standard CPMP/unit: $912 (for 3 or less), $800 (for 4 to 25 units); $720 (for more than 25 units). TDR cable: available in length of 100 to 1000 ft increments (individual quote).
	Data acquisition system	Individual quote for advanced CPMP (built in digital data loggers) and TDR instrument.
	Communication system	
	Data archiving system	
	Other	
Software		
Labor	Installation	
	Use	
Other:		

4. Limitations	
Life expectancy	30 years plus.
Power	Standard batteries for hand-held voltmeter. Main line power supply for data logger.
Environmental conditions	-30 to 70°C.
Data storage/transfer/ processing	
Other:	

5. Implementation Needs	
Power source	Battery, AC/DC.
Accessibility	Direct access needed for data acquisition.
Technical expertise	Minimal training. Basic electronics and computer skills.
Other: Window based PC with Microsoft EXCEL software.	

6. Availability
2 to 8 weeks.

7. On-Going or Completed Bridge Related Projects and References
US20 Bridge, Grundy County, Iowa, 2002. Lieserschlucht Bridge, Austria, 2001. Vancouver HPC Beam Bridge, Vancouver, Canada, 2000. Murderkill River Bridge, Frederica, Delaware, 1999. Pilsen Arch Bridge, Pilsen, Czech Republic, 1995. Many other projects in many countries. References: • Lee, Y.S. "Evaluation of Bridges Strengthened or Newly Constructed with Innovative Materials," MS Thesis, Iowa State University, Ames, Iowa, 2003. • Weitek, B. "Monitoring the Corrosion of Steel in Concrete," FIP Symposium on Post-tensioned Concrete Structures 1996, London, UK, September 1996.

8. Notes
• VETEK is a US corporation affiliated with CMS in Austria. • The use of VETEK's embeddable sensors offers an ability to monitor an interior state of a structure by measuring parameters that can be used as reliable indicators of the likelihood of corrosion in the surrounding area. Although the sensor does not address the specific electrochemical mechanisms, it provides a monitoring system to measure the basic electrochemical processes. • For existing structures, some destruction is required in order to install the necessary monitoring sensors/cables.

1. General Information

Description of Technology	Manufacturer of vibration sensing products: accelerometers (vibration sensors), accelerometer power supplies, accelerometer switch boxes, online Condition Based Management Systems, and accelerometer accessories.		
Manufacturer and Contact information	Vibra-Metrics 195 Clarksville Road, Princeton Jct, NJ 08550	www.vibrametrics.com Tel: (609) 716-4130 Fax: (609) 716-0706	
Features	Sensor type	Accelerometers. Model CBM 2000: 1,500 mV/g, low frequency response, rugged design, low impedance signal suitable for long cable lengths (up to 1,000 ft). Model 1030: 5,000 mV/g minimum output, low noise, low frequency. Model 5102 shear design accelerometer: 500 mV/g, ISOSHIELD internal electrical isolation.	
	Data acquisition, processing, and archiving	Sensor Highway (condition based monitoring systems): low-cost, advanced on-line monitoring system capable of monitoring of up to 4,000 points (or 4,000 sensors) ; monitoring of almost any parameter (vibration, temperature, pressure, etc).	
	Communications	Direct wire connection, Ethernet/Internet or other wireless communications upon request.	
	'Smart' attributes	Vibra-Metrics' patented Sensor Highway based monitoring systems offer fully automated, unattended remote data acquisition and alarm reporting.	
	Other	Power supply devices: single and multi-channel low noise, portable battery powered accelerometer power supplies, as well as line powered units designed for lab use, rack mount, and other applications.	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☐ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☒ Cover plate ☒ Stiffener ☐ Other:	☐ Riveted/bolted ☒ Cross	☐ Welded ☒ Lateral	☐ Pin & hanger ☒ Sway	☐ Splice	
	Bearing ☒ Fixed ☒ Expansion: ☐ Other:	☒ Sliding plate	☒ Roller	☒ Rocker	☒ Pin and link	☒ Elastomeric ☒ Pot ☒ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☐ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☐ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☒ Main/secondary cable ☐ Cable anchorage ☐ Anchor rod ☐ Damping system ☐ Strand shoes ☐ Cable bands ☐ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:					
	Other:					

Monitoring Interest

☒ Crack/fracture ☐ Expansion/contraction ☐ Rotation/torsion ☐ Wear/spalling/scaling/delamination
☒ Section loss ☐ Settlement ☐ Misalignment ☐ Connection failure or deficiencies
☐ Deformation ☐ Wire breakage ☐ Mechanical/electrical malfunction ☐ Impact damage
☐ Debonding ☐ Erosion/scour ☐ Looseness and pounding ☐ Excessive joint closing/opening
☐ Corrosion ☐ Environmental ☐ Other:

Measurement Metric

☐ Strain ☐ Deflection/displacement ☒ Acceleration/vibration ☐ Moisture/humidity level
☐ Temperature ☐ Magnetic field/flux ☐ Electrical voltage/current ☐ Chemical composition
☐ Radar waves ☐ Acoustic waves ☐ Magnetic waves ☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☐ Wind speed/direction ☒ Other: Sensor Highway system can measure all most any parameters.

3. Cost		
Hardware	Sensor	CBM 2000: $1,295 per unit. Model 1030: $1,390 per unit. Model 5102: $550 per unit.
	Data acquisition system	Sensor Highway system is priced based on specification.
	Communication system	
	Data archiving system	
	Other	12-channel amplifier integrator (digital level meter switch selectable, rack mount filgers): $8,695. 6-channel power supply signal conditioner (including fault and clipping indicators, isolated outputs): $2,595.
Software		
Labor	Installation	
	Use	
Other: Miniature battery power supply (single channel): $255 (15V DC, 2mA output), $415 (Ni-Cad battery, 3 position gain switch, 24V DC output). 110V AC line-input power supplies: $510 (10-32/BNC, 24V DC), $650 (3 channels, 24V DC), $835 (6 channels, rack mount, 24V DC), $1,170 (12 channels).		

4. Limitations	
Life expectancy	No official life expectancy.
Power	15 to 30V DC. 110/220V AC.
Environmental conditions	Accelerometers: -40 to 121°C.
Data storage/transfer/ processing	
Other:	

5. Implementation Needs	
Power source	Battery, AC/DC.
Accessibility	On-line remote monitoring.
Technical expertise	Minimal training. Basic electronics and computer skills. Technical support available on-line or by phone.
Other: Window based PC.	

6. Availability

Accelerometers: 2 to 5 weeks.
Sensor Highway system: 3 months.

7. On-Going or Completed Bridge Related Projects and References

Bridge related project information not available.

8. Notes

- For nearly thirty years, Vibra-Metrics has designed, manufactured and supplied vibration sensing products including accelerometers (vibration sensors), accelerometer power supplies, accelerometer switch boxes, online Condition Based Management Systems, and accelerometer accessories.
- The company offers a broad array of engineering, design and support services for various applications.
- The Sensor Highway is capable of collecting vibration, temperature, pressure and other parameter data from up to 4000 sensors throughout a facility and transporting the information back to the controller or a processing PC for surveillance and analysis.
- The Vibralarm Supervisory System is a key feature of the on-line Sensor Highway System; it allows vibration monitoring on site and from remote locations anywhere via modem.
- Vibralarm's advanced software provides a wide range of graphical applications that are simple to use; real-time vibration data can be quickly accessed through Vibralarm's various graphical display screens.
- To access the information the user clicks or points to a particular area of the screen; the system then advances to the next display that provides additional vibration data.
- Displays include the Bar graph Screen, Unit or Group Display and the Channel Screen.

1. General Information

Description of Technology	Manufacturer and supplier of accelerometers and vibration sensors.		
Manufacturer and Contact information	Wilcoxon Research, Inc. 21 Firstfield Road, Gaithersburg, Maryland 20878	www.wilcoxon.com Tel: (301) 330-8811 Fax: (301) 330-8873	
Features	Sensor type	Acclerometers (high frequency and low frequency) and vibration sensors. Seismic accelerometer and power amlifier system (model 731A/P31): high sensitivity, low-frequency capable, low-noise electronics at sub micro-g levels, ESD protection, and mis-wiring protection.	
	Data acquisition, processing, and archiving		
	Communications		
	'Smart' attributes		
	Other	Other various type of accelerometers and vibration sensors are availble (e.g., general purpose accelerometers and high temperature accelerometers).	

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☒ Timber:	☒ Plank ☐ Other:	☒ Nailed laminated	☒ Glue-laminated	☒ Prestressed laminated	☒ Stressed timber
	☒ Concrete:	☒ Reinforced ☐ Other:	☒ Prestressed/post-tensioned			
	☒ Steel:	☒ Grid ☐ Other:	☒ Orthotropic	☒ Buckle plate	☒ Corrugated steel flooring	
	☒ FRP:					
Superstructure	*Primary Element* ☒ Multi-beam/girder system: ☒ Slab ☒ Truss member ☒ Arch element ☐ Other:	☒ Girder floor beam/diaphragm system	☒ Tee beam	☒ Box girder	☒ Channel beam	
	Secondary Element ☐ Connector and fastener: ☒ Bracing: ☒ Diaphragm ☐ Cover plate ☐ Stiffener ☐ Other:	☐ Riveted/bolted ☐ Cross	☐ Welded ☐ Lateral	☐ Pin & hanger ☐ Sway	☐ Splice	
	Bearing ☐ Fixed ☐ Expansion: ☐ Other:	☐ Sliding plate	☐ Roller	☐ Rocker	☐ Pin and link	☐ Elastomeric ☐ Pot ☐ Restraining
	Other:					
Substructure	☒ Abutment:	☒ Footing ☐ Other:	☒ Bridge seat	☒ Piles	☒ Wall (stem/back/wing)	
	☒ Pier/bent/extended pile:	☒ Pier cap ☐ Other:	☒ Shaft	☒ Column/stem	☒ Submerged pile/pile cap/footing	
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)* 1. Cable-supported bridge ☒ Tower ☐ Strand shoes 2. Movable bridge ☒ Electric brakes	☐ Main/secondary cable ☐ Cable bands ☒ Motors and power	☐ Cable anchorage ☐ Cable enclosures ☒ Operating machinery and equipment	☐ Anchor rod ☐ Other:	☐ Damping system ☐ Other:	
	Other:					

Monitoring Interest

☒ Crack/fracture	☐ Expansion/contraction	☐ Rotation/torsion	☐ Wear/spalling/scaling/delamination
☐ Section loss	☐ Settlement	☐ Misalignment	☐ Connection failure or deficiencies
☐ Deformation	☐ Wire breakage	☒ Mechanical/electrical malfunction	☒ Impact damage
☐ Debonding	☐ Erosion/scour	☐ Looseness and pounding	☐ Excessive joint closing/opening
☐ Corrosion	☒ Environmental	☒ Other: Seismic activity.	

Measurement Metric

☐ Strain	☐ Deflection/displacement	☒ Acceleration/vibration	☐ Moisture/humidity level
☐ Temperature	☐ Magnetic field/flux	☐ Electrical voltage/current	☐ Chemical composition
☐ Radar waves	☐ Acoustic waves	☐ Magnetic waves	☐ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves	☐ Wind speed/direction	☐ Other:	

3. Cost		
Hardware	Sensor	General purpose acclerometers: $69~$370 per unit. High temperature accelerometer: $395 per unit. Low frequency acclerometer: $335~$375 per unit. High frequency accelerometer: $325 per unit. Velocity loop powered Sensors: $275~$445 per unit.
	Data acquisition system	
	Communication system	
	Data archiving system	
	Other	Seismic Accelerometer and Power Amplifier System (731A/P31) with R6-2T-J9-10 cable: $1,250.
Software		
Labor	Installation	
	Use	
Other: MaxFlex Data collection cables: $70~$180 each. Cable termination box: $90 (for 2-channel) ~ $135 (for 4-channel). Magnetic mounting base: $90~$150 each.		

4. Limitations	
Life expectancy	No official life expectancy.
Power	Model 731A/P31: Two 9V Alkaline for internal batteries (>75 hours of battery life). Low frequency accelerometers and General purpose accelerometers: 18-30V DC.
Environmental conditions	Model 731/P31: -10 to 60°C temperature range, vibration limit of 10g peak. Low frequency accelerometers and General purpose accelerometers: -50 to 120°C temperature range.
Data storage/transfer/ processing	
Other:	

5. Implementation Needs	
Power source	Battery, DC.
Accessibility	Direct access needed for sensor installation.
Technical expertise	Minimal. Training available.
Other:	

6. Availability

1 to 4 weeks for standard products.

7. On-Going or Completed Bridge Related Projects and References

EL Hormiguero Bridge, Colombia.

References:

- Thomson, P., Marulanda, J., and Caicedo, J. "Real time health monitoring of civil infrastructure systems in Colombia," Proceedings of SPIE, 2001.
- Caicedo, J.M., Marulanda, J., Thomson, P., and Dyke, S.J. "Monitoring of Bridges to Detect Changes in Structural Health," Proceedings of the 2001 American Control Concrete, Arlington, Virginia, 2001.

8. Notes

- Wilcoxon Research was founded in 1960 and has been manufacturing a wide range of vibration instrumentation.
- Other available manufacturing and test equipment ranges from basic precision machinery for providing high quality sensor components, to custom-built machinery specifically designed for transducer fabrication.
- Wilcoxon offers customized training programs both on and off-site. Training topics include vibration analysis, sensor technology, installation tips and techniques, sensor selection and others upon request.

1. General Information

Description of Technology	Computer Assisted Radar Tomography (CART) system for mapping and monitoring concrete or asphalt deck or shallow subsurface; CART system uses a Ground Penetrating Rader (GPR) array.	
Manufacturer and Contact information	Witten Technologies, Inc. (WTI) 14205 Burnet Rd, Suite 210, Austin, Texas 78728	www.wittentech.com Tel: (512) 388-1112 Fax: (512) 388-1114
Features	Sensor type	The standard CART system uses a fixed array of 9 transmitters and 8 receivers. Each radar element in the array is a standard ultra-wideband GPR that broadcasts an impulse with a frequency spectrum from about 50 to 400 MHz
	Data acquisition, processing, and archiving	The array is controlled by special electronics that fire the transmitter elements and controls the receivers in sequence to create 16 standard bi-static GPR channels covering a 2 m swath on the ground. In this standard "bi-static" mode of operation, each transmitter fires twice in sequence, with each firing being recorded by an adjacent receiver. Image processing and visualization software is used to extract feasures from the 3D radar images.
	Communications	
	'Smart' attributes	
	Other	A multi-static mode, in which each transmitter fires once in sequence and is recorded by all the receivers, is also possible. On paved surfaces or flat terrains, the CART system can cover 3,000 linear feet per hour.

2. Applicability

Bridge Type

☒ Slab ☒ Girder/Deck ☒ Truss ☒ Arch
☒ Rigid Frame ☒ Suspension ☒ Cable-stayed ☒ Vertical lift
☒ Swing ☒ Bascule ☐ Other:

Bridge Component

Deck	☐ Timber:	☐ Plank ☐ Nailed laminated ☐ Glue-laminated ☐ Prestressed laminated ☐ Stressed timber ☐ Other:
	☒ Concrete:	☒ Reinforced ☒ Prestressed/post-tensioned ☐ Other:
	☐ Steel:	☐ Grid ☐ Orthotropic ☐ Buckle plate ☐ Corrugated steel flooring ☐ Other:
	☐ FRP:	
Superstructure	*Primary Element*	☐ Multi-beam/girder system: ☐ Girder floor beam/diaphragm system ☐ Tee beam ☐ Box girder ☐ Channel beam ☒ Slab ☐ Truss member ☐ Arch element ☐ Other:
	Secondary Element	☐ Connector and fastener: ☐ Riveted/bolted ☐ Welded ☐ Pin & hanger ☐ Splice ☐ Bracing: ☐ Cross ☐ Lateral ☐ Sway ☐ Diaphragm ☐ Cover plate ☐ Stiffener ☐ Other:
	Bearing	☐ Fixed ☐ Expansion: ☐ Sliding plate ☐ Roller ☐ Rocker ☐ Pin and link ☐ Elastomeric ☐ Pot ☐ Restraining ☐ Other:
	Other:	
Substructure	☐ Abutment:	☐ Footing ☐ Bridge seat ☐ Piles ☐ Wall (stem/back/wing) ☐ Other:
	☐ Pier/bent/extended pile:	☐ Pier cap ☐ Shaft ☐ Column/stem ☐ Submerged pile/pile cap/footing ☐ Other:
Miscellaneous	*Additional Element for special types of bridge (Cable-supported, Movable bridge, etc)*	1. Cable-supported bridge ☐ Tower ☐ Main/secondary cable ☐ Cable anchorage ☐ Anchor rod ☐ Damping system ☐ Strand shoes ☐ Cable bands ☐ Cable enclosures ☐ Other: 2. Movable bridge ☐ Electric brakes ☐ Motors and power ☐ Operating machinery and equipment ☐ Other:
	Other:	

Monitoring Interest

☒ Crack/fracture ☐ Expansion/contraction ☐ Rotation/torsion ☒ Wear/spalling/scaling/delamination
☐ Section loss ☐ Settlement ☒ Misalignment ☐ Connection failure or deficiencies
☒ Deformation ☒ Wire breakage ☐ Mechanical/electrical malfunction ☒ Impact damage
☒ Debonding ☐ Erosion/scour ☐ Looseness and pounding ☐ Excessive joint closing/opening
☒ Corrosion ☐ Environmental ☐ Other:

Measurement Metric

☐ Strain ☐ Deflection/displacement ☐ Acceleration/vibration ☐ Moisture/humidity level
☐ Temperature ☐ Magnetic field/flux ☐ Electrical voltage/current ☐ Chemical composition
☒ Radar waves ☐ Acoustic waves ☐ Magnetic waves ☒ Electromagnetic waves (X-ray, gamma ray, etc)
☐ Thermal waves ☐ Wind speed/direction ☐ Other:

3. Cost		
Hardware	Sensor	
	Data acquisition system	
	Communication system	
	Data archiving system	
	Other	
Software		
Labor	Installation	
	Use	
Other: Cost depends on the area surveyed and surface conditions, but is typically between $0.15 to $0.40 per sq ft; an average of about $0.25 per sq ft.		

4. Limitations	
Life expectancy	No official life expectancy.
Power	
Environmental conditions	
Data storage/transfer/ processing	50 to 400 MHz bandwidth. 16 channels at 1 ft/s (1km/hr).
Other: Resolution is approximately 2 to 3 inches.	

5. Implementation Needs	
Power source	Batterry.
Accessibility	Direct access needed for monitoring.
Technical expertise	Moderate training on how to operate the system.
Other:	

6. Availability

Upon agreement.

7. On-Going or Completed Bridge Related Projects and References

Information not available.

8. Notes

- WTI was founded in 1994 and offers geophysical mapping services using the CART system. Over the past two years WTI has surveyed and interpreted over 2 million square feet of radar data.
- The radar array in the CART Imaging System can be mounted in a trailer that is towed by a vehicle or in a deck mount in front of a commercial riding lawnmower.
- A system with higher-frequency elements, having a spectrum between 100 and 650 MHz, has also been tested.
- MALÅ GeoScience (www.malags.com) is the manufacturer of the CART imaging system hardware.

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