BDI
RAW DATA. REFINED RESULTS.

PAVEMENT INSTRUMENTATION AND MONITORING

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AGENDA

- **PAVEMENT TESTING**

- **PAVEMENT INSTRUMENTATION**

- **DATA SYSTEMS AND SOFTWARE**

- **CASE STUDY APPLICATIONS**

- **NEW TECHNOLOGY**

PAVEMENT EXPERIENCE

Tom Weinmann, formerly with Geocomp/AGI/CTL has recently joined BDI to bring a new depth of experience with regards to pavement monitoring and custom pavement monitoring sensors.

+ BDI's pavement sensor design Engineer has been providing this line of pavement instrumentation to research institutions for more than 20 years. These institutions include the accelerated pavement test facilities for the FAA, FHWA, NCAT, MnRoad, USACE, Korean Highway Department and Universities across the globe. Coupled with BDI's data acquisition hardware and software capabilities, complete pavement instrumentation solutions can be provided.

+ While similar instruments may be supplied by others, only BDI provides the in-house expertise for the design, installation and integration of complete turn-key system solutions based on user experience and feedback from these leading institutions.

NATIONAL AIRPORT TEST FACILITY

FAA TEST FACILITY WITH 1000+ SENSORS!

+ Concrete Strain Gages
+ Asphalt Strain Gages
+ Temperature Trees
+ Soil Compression Gages
+ Soil Pressure Cells
+ Soil Moisture Gages
+ Multi-Depth Deflectometer
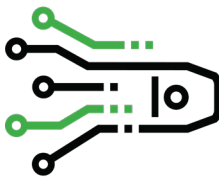+ Track-side ADAS
+ Control Room

PAVEMENT TESTING/MONITORING

ACCELERATED PAVEMENT TEST FACILITIES
AND VEHICLES

HOW DO YOU MEASURE PAVEMENT RESPONSES

1. **Pavements**
   I. Asphalt Strain Gages
   II. Concrete Strain Gages
   III. Temperature Tree
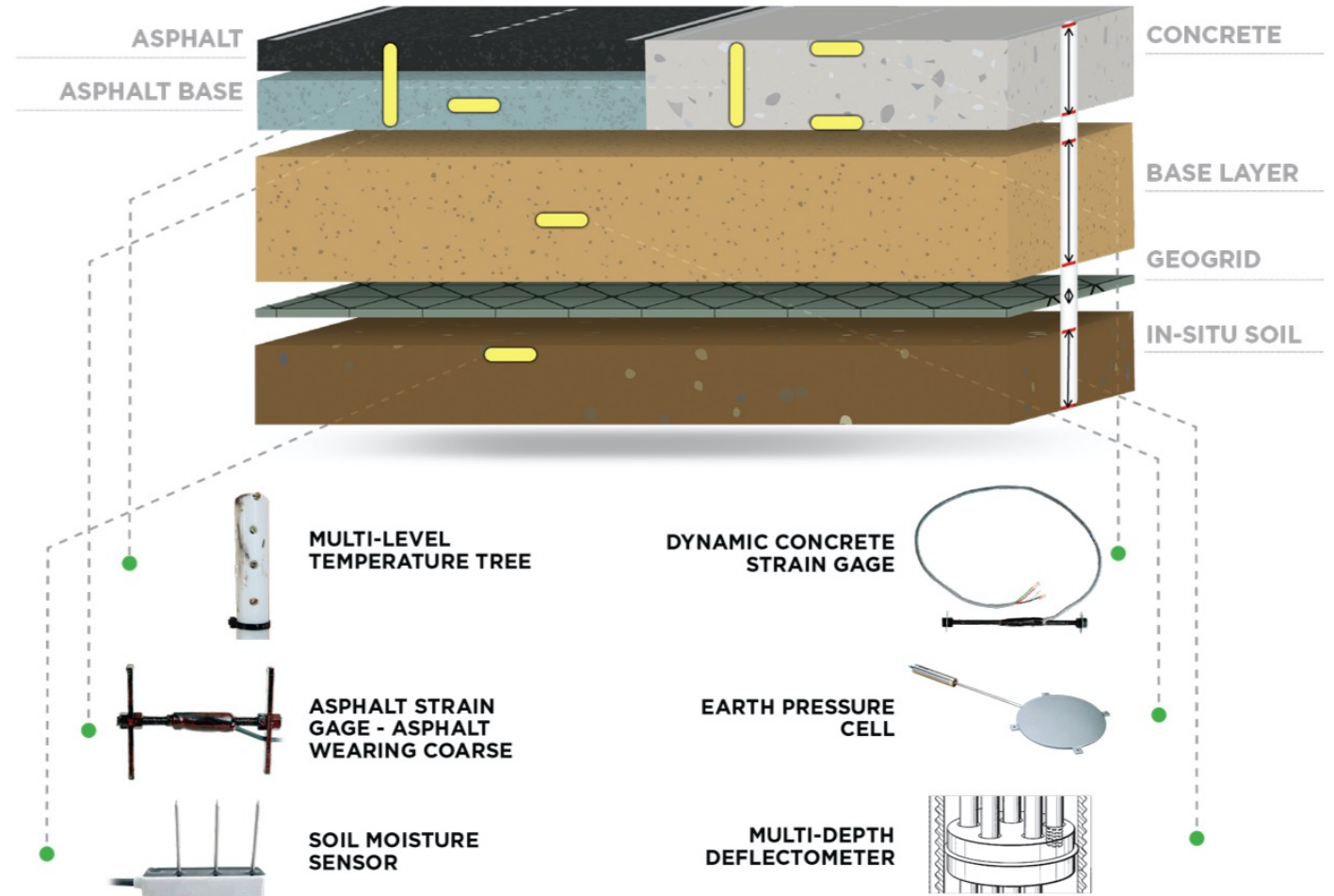   IV. Multi-Depth Deflectometer

2. **Base Layers**
   I. Pressure Cells
   II. Multi-Depth Deflectometer
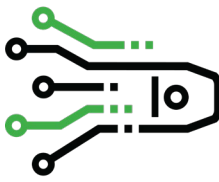   III. Vertical Strain
   IV. Rotation

3. **Geogrid**
   I. Geogrid Strain

4. **Sub-Base Layers**
   I. Pressure Cells
   II. Multi-Depth Deflectometer
   III. Soil Compression
   IV. Rotation
   V. Soil Moisture

ASPHALT
ASPHALT BASE
CONCRETE
BASE LAYER
GEOGRID
IN-SITU SOIL

MULTI-LEVEL TEMPERATURE TREE

DYNAMIC CONCRETE STRAIN GAGE

ASPHALT STRAIN GAGE - ASPHALT WEARING COARSE

EARTH PRESSURE CELL

SOIL MOISTURE SENSOR

MULTI-DEPTH DEFLECTOMETER

BDI RAW DATA. REFINED RESULTS.

SENSOR TECHNOLOGY

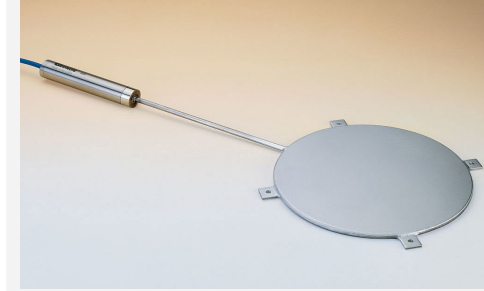| ASPHALT STRAIN	VERTICAL STRAIN	TEMP TREE	MULTI-DEPTH DEFLECTOMETER	EARTH PRESSURE
+ Range: ±3000 µε + 350Ω Fully Active Wheatstone bridge + Sensitivity: 1.3 mV$_{out}$/mV$_{ext}$ + Reusable, waterproof + Temperature Range: -50 to +200 °C	+ Range: ±3000 µε + 350Ω Fully Active Wheatstone bridge + Sensitivity: 1.3 mV$_{out}$/mV$_{ext}$ + Reusable, waterproof + Temperature Range: -50 to +200 °C	+ Temperature Range: -50 to +200 °C + Depth of Measurement: User defined	+ Gage Length: Customer Specified + Measurement Rage: up to 6in (150mm) + 3- to 4-wire potentiometer + Temperature Range: -_20_ °C to +85 °C	+ Range: ±0.5 in, ±1.0 in, ±2.0 in, ±3.0 in + Output: ±2.2 Vdc + Linearity: < ±0.5% F.S. + Temperature Range: -40 to +80 °C + Temp. Coefficient: ±0.0306% F.S/ °C

BDI | RAW DATA. REFINED RESULTS.
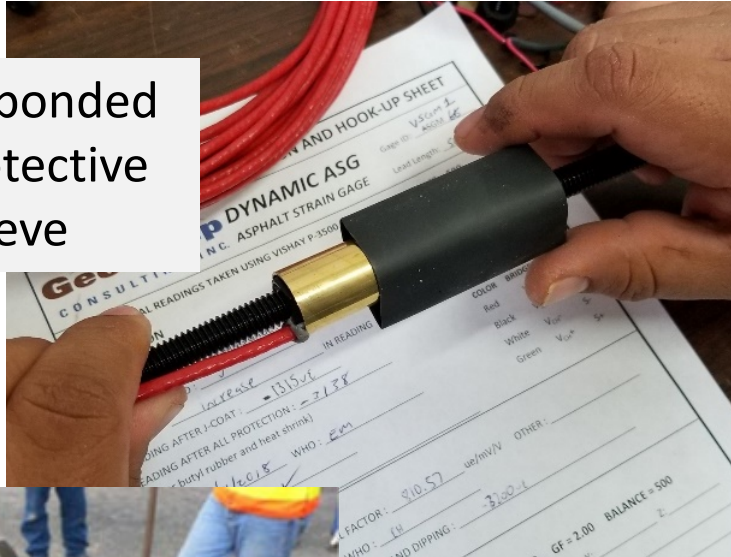
ASPHALT STRAIN (DYNAMIC)
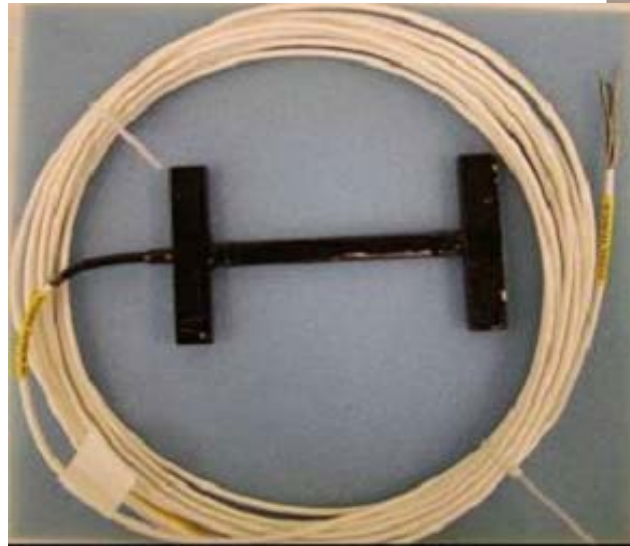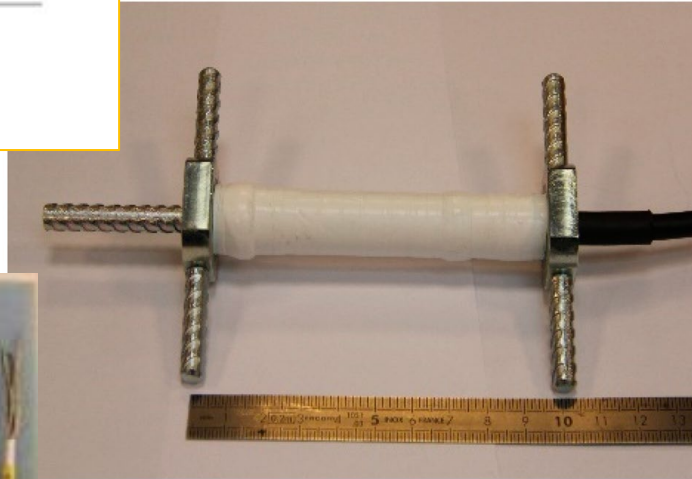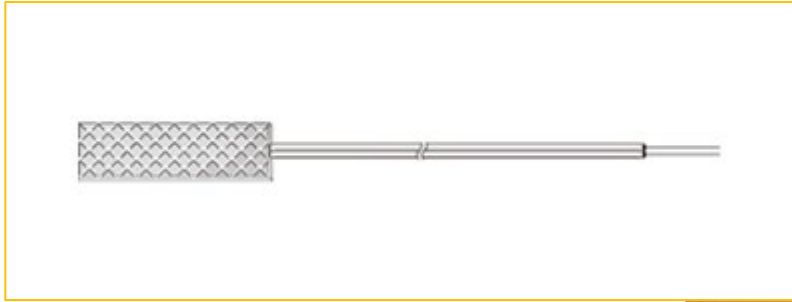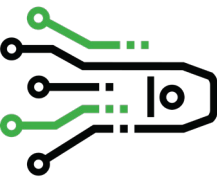
ASPHALT STRAIN GAGE
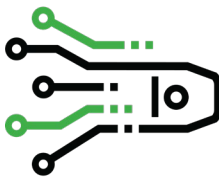## MAJOR IMPROVEMENTS FOR INCREASED SURVIVAL RATES (>90%)
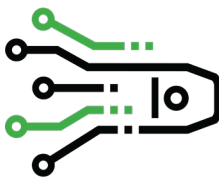
INSTALL EXPERIENCE STILL IMPORTANT

Unbonded Protective Sleeve
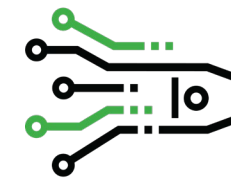
ASPHALT STRAIN GAGE
OFTEN IMITATED – NEVER DUPLICATED

- Design by Civil Engineer with hands-on experience with more than 1000 sensor installations

- Dynamic calibration of sensor (how it's used).

- Final coating is bitumen- not driveway sealer

- Unbonded crush protection

- Fabrication by a 'true' sensor manufacturer in a production facility

- Soon to have single matrix gage grid to eliminate delicate gage wiring

Above and continued improvements based on continuous interaction with the Test Pavement community (TRB AFD40 APT)
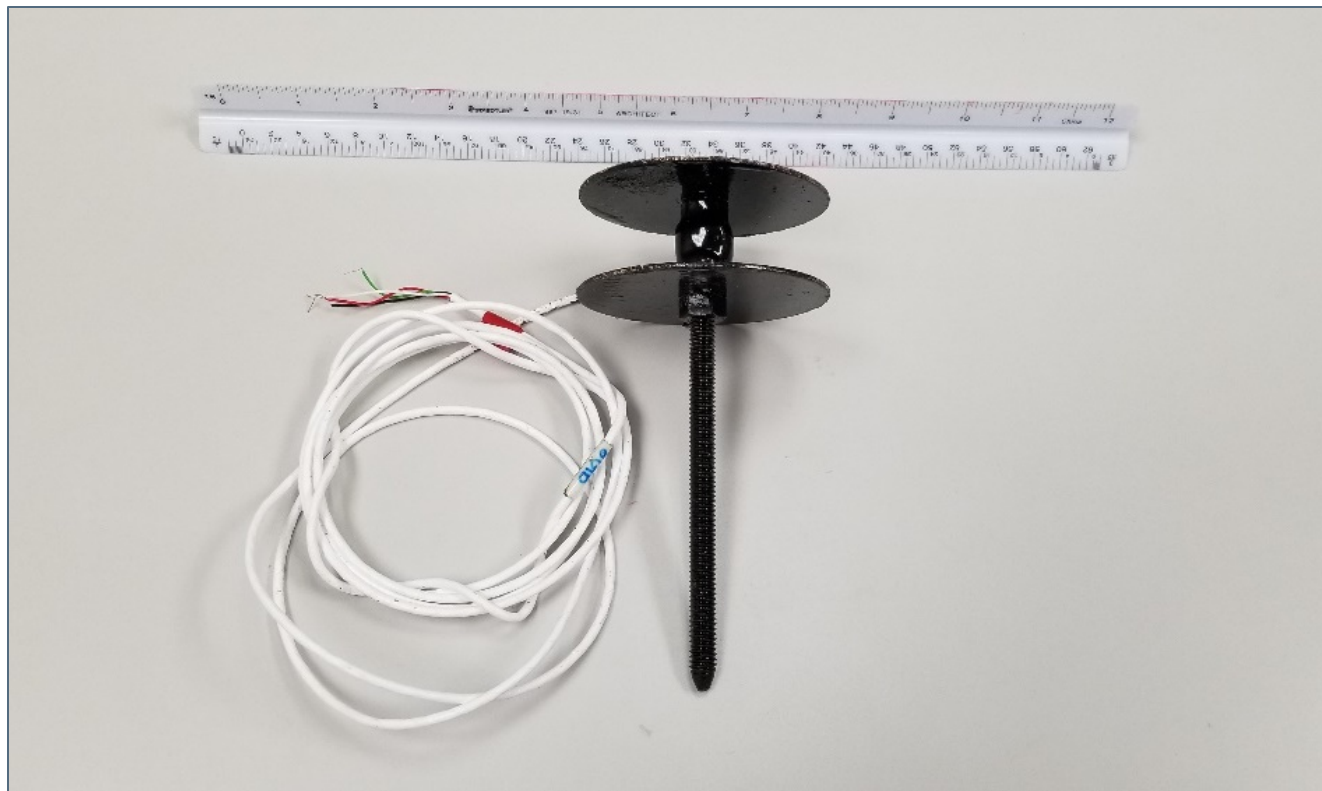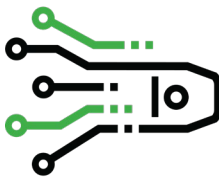
VERTICAL ASPHALT STRAIN GAGE (DYNAMIC)
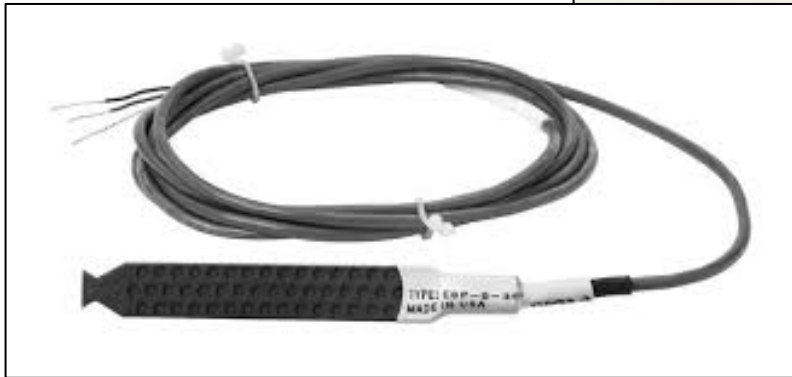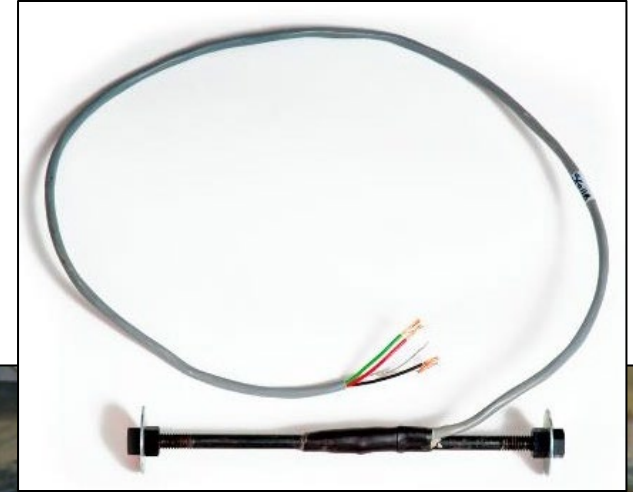
USED IN ASPHALT OR SOIL

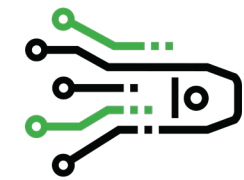CAN BE USED FOR TRIGGERING DATA COLLECTION OR CAMERAS

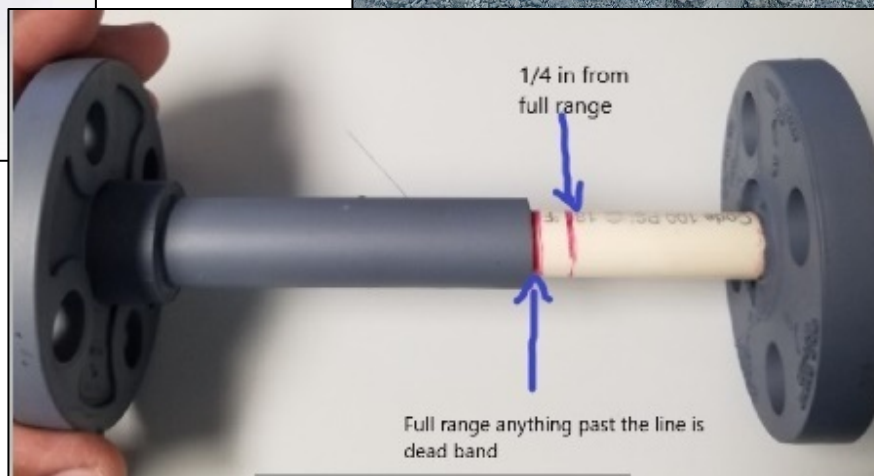# CONCRETE STRAIN GAGE (DYNAMIC)

WOULD NOT RECOMMEND FOR CONCRETE STABILIZED BASE- CONCRETE ONLY
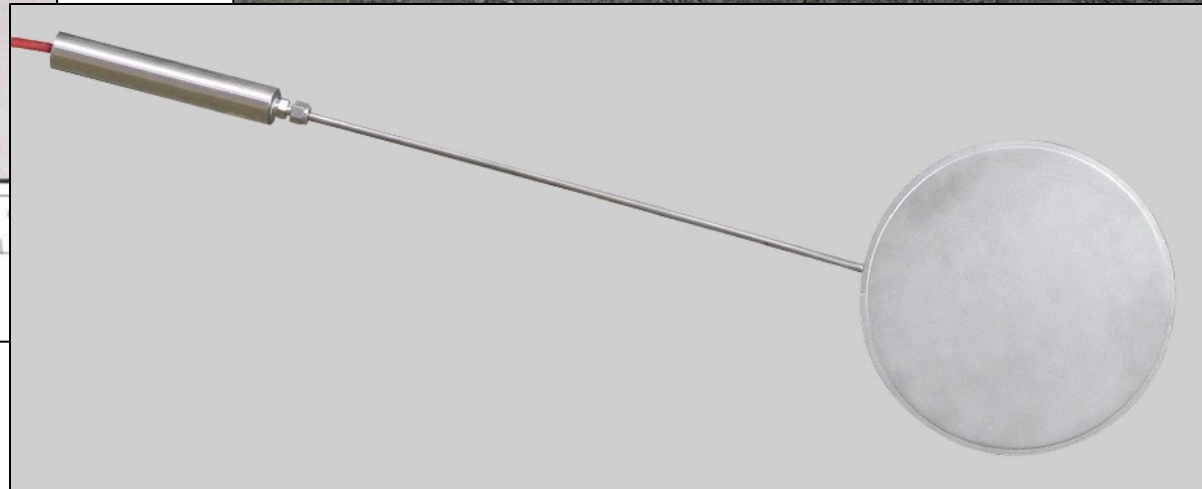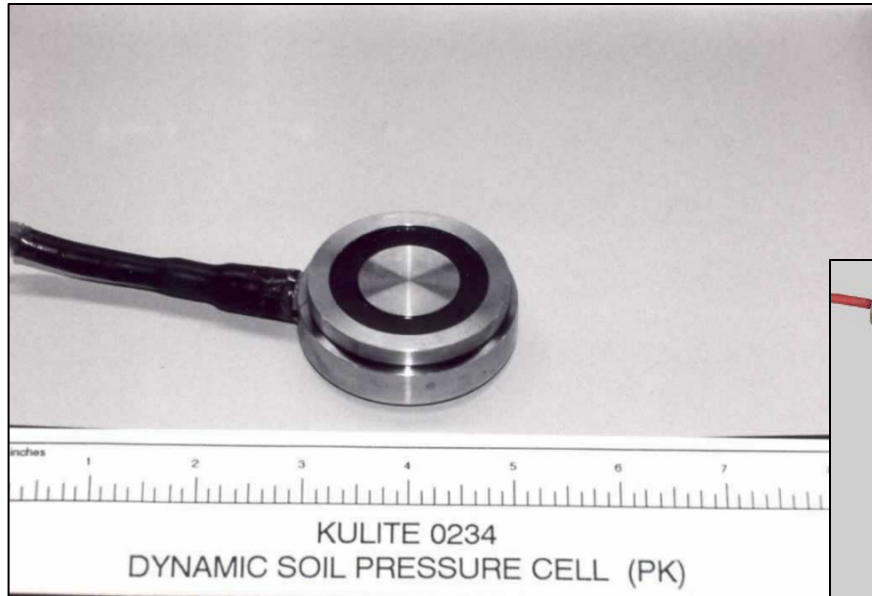
SOIL COMPRESSION SENSOR (DYNAMIC)

RUGGEDIZED
USED HORIZONTAL OR VERTICAL
BEST ABOVE THE WATER TABLE

EARTH PRESSURE CELL (DYNAMIC)

BEDDING IS MOST IMPORTANT
CAREFUL UNDER CONCRETE
VENDER MAY NOT HAVE ALL THE ANSWERS

KULITE 0234
DYNAMIC SOIL PRESSURE CELL (PK)

EARTH PRESSURE CELL (DYNAMIC)

CAREFUL WITH THE RANGE SELECTION
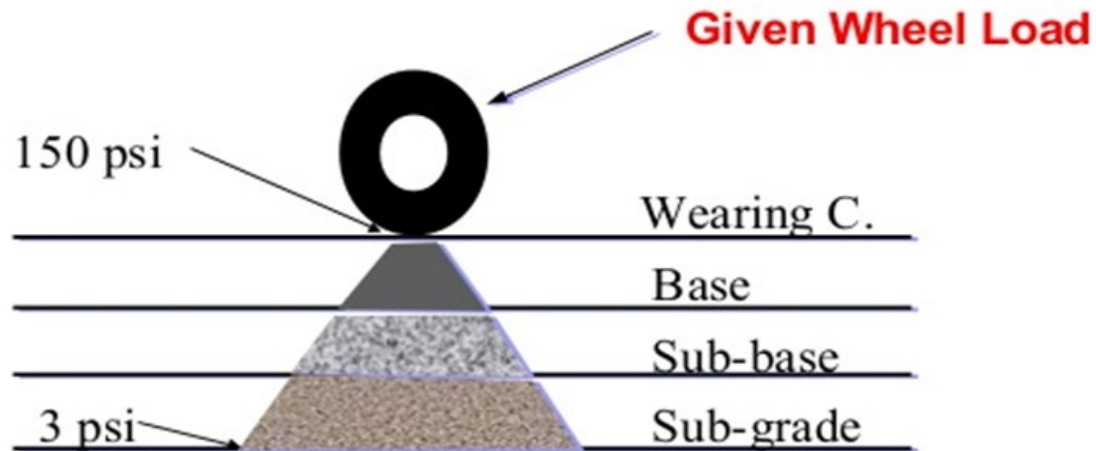
SHOULD YOU CALIBRATE?
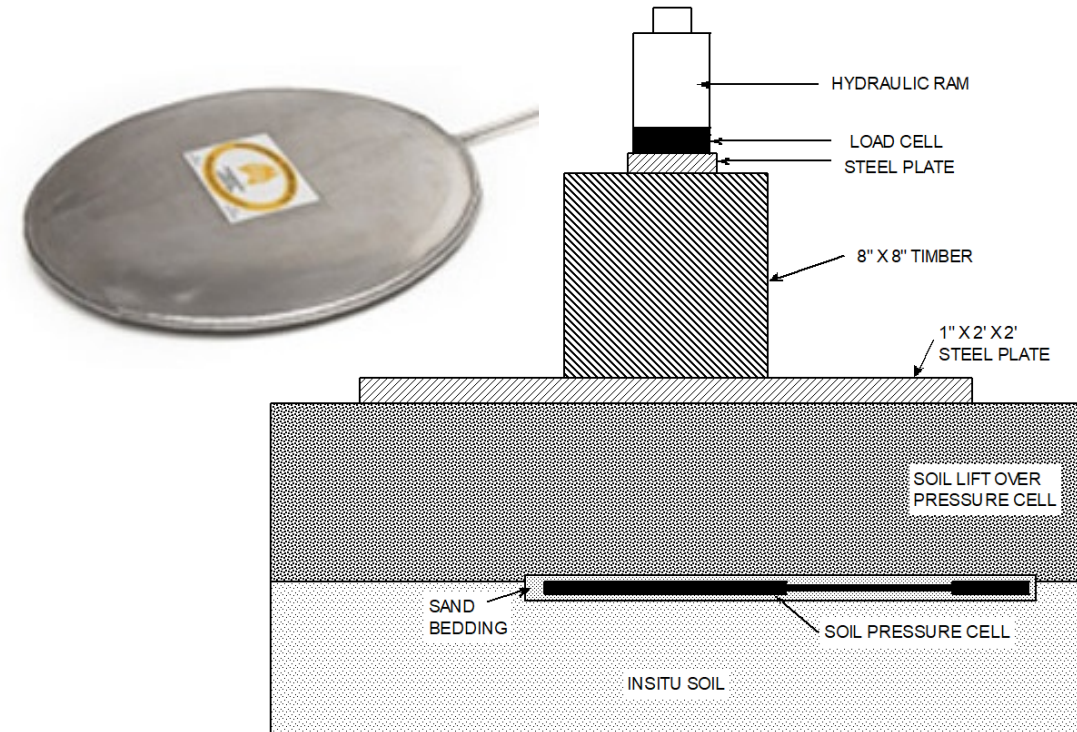
GEOGRID STRAIN (DYNAMIC)
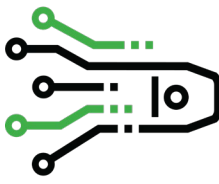
MULTI-DEPTH DEFLECTOMETER (DYNAMIC)
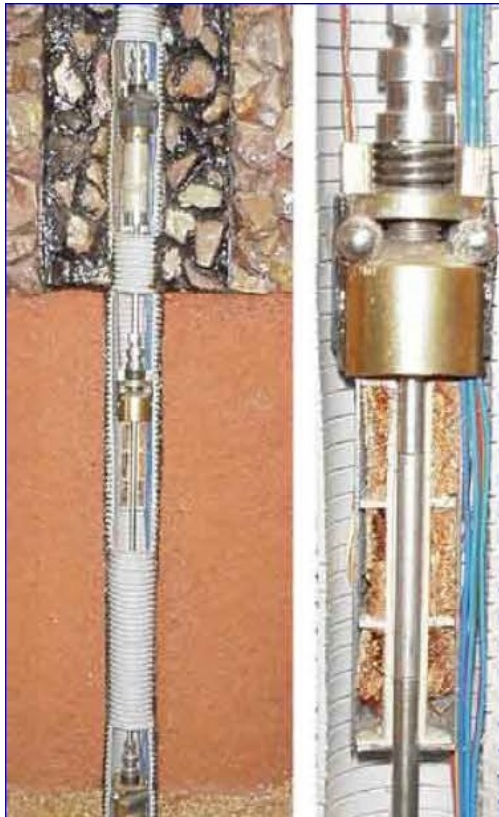
DYNATEST MDD

- LINEAR ARRAY
- SENSORS IN GROUND
- SENSOR NOT REPLACEABLE
- 2 DAY INSTALLATION
- MDD COST - $$$$
- INSTALLATION COST - $$$$
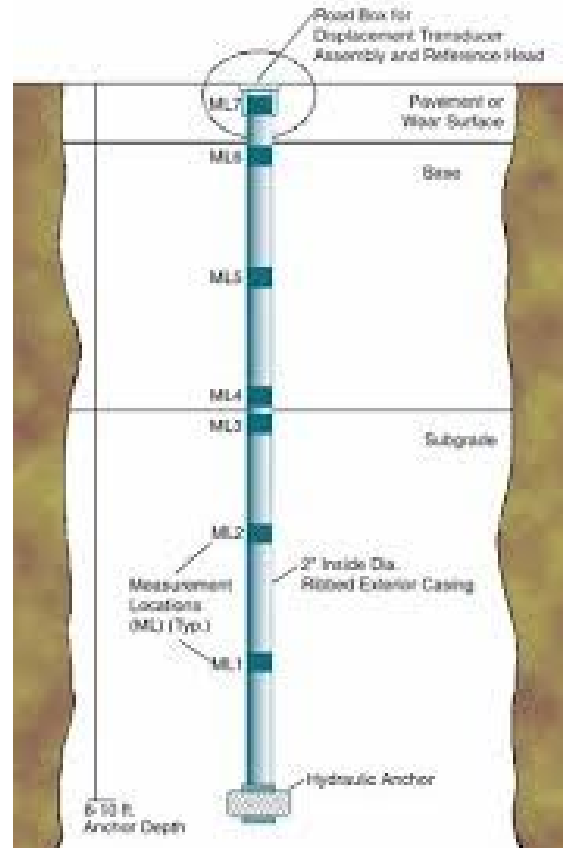
BDI MDD

- PARALLEL ARRAY
- SENSORS IN ROADBOX
- SENSORS RE-STROKEABLE
- PREFABRICATED
- 2 PER DAY INSTALLATION
- MDD COST - $$$
- INSTALLATION COST - $$

MULTI-DEPTH DEFLECTOMETER (DYNAMIC)

SLAB TRACK RAIL - TTCI

COAL MINING HAUL ROADS - CATERPILLAR

LOGGING ROADS – MINISTRY OF FORESTRY MANNITOBA

ACCELERATED PAVEMENT TESTING – NUMEROUS CLIENTS
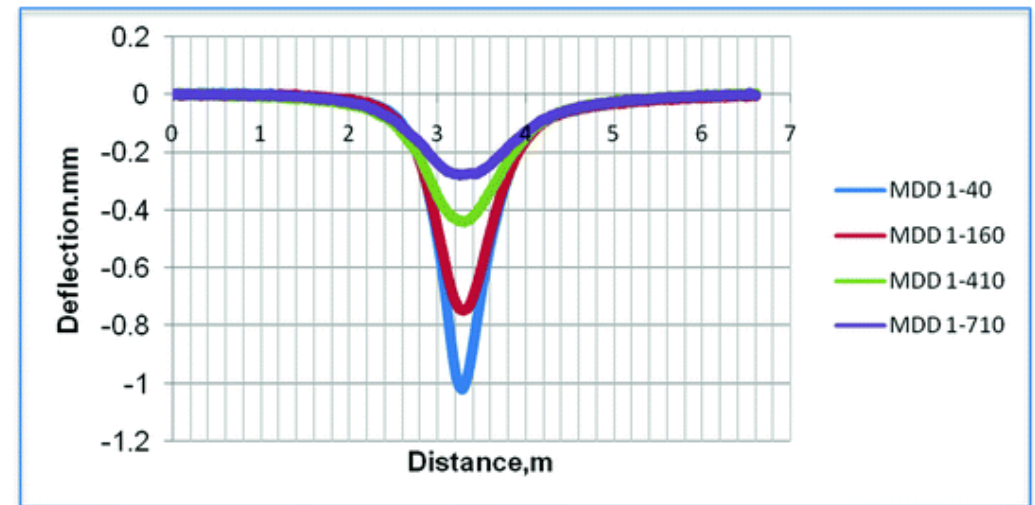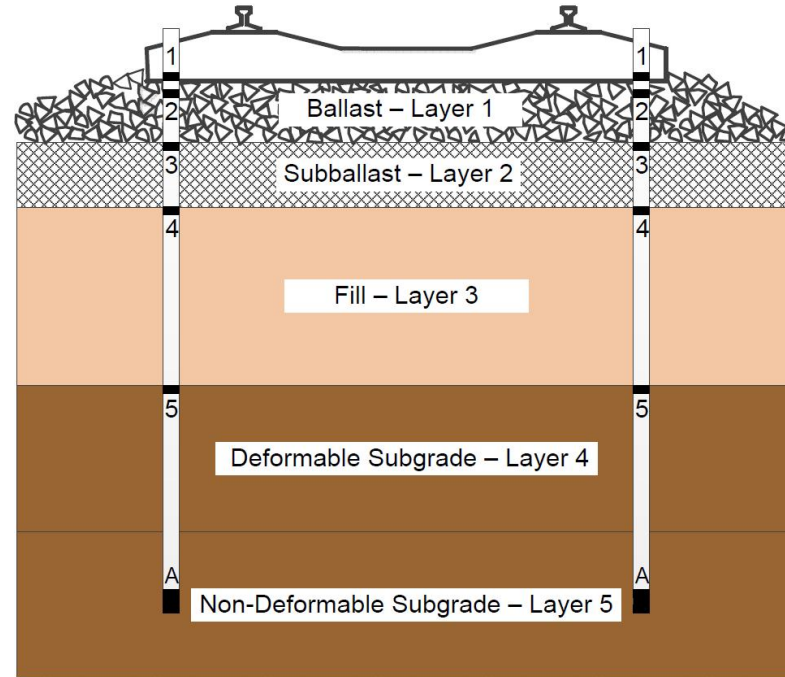
SOIL MOISTURE (STATIC)

RESISTANCE TYPE NOT RESEARCH GRADE
TDR/CAPACITANCE SHOULD BE CALIBRATED FOR SOIL TYPE
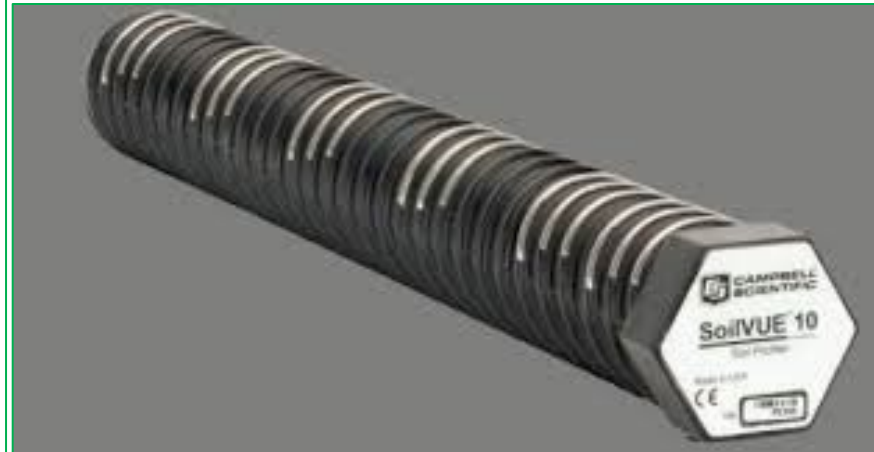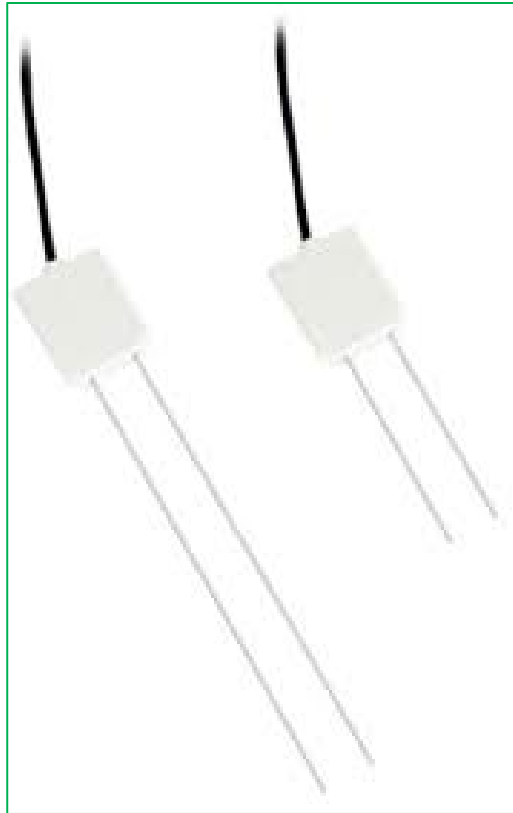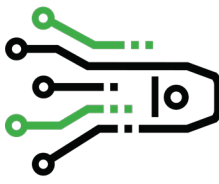
TEMPERATURE GRADIENT (STATIC)

FOR ASPHALT OR CONCRETE
CAN BE TC, RTD OR THERMISTOR- WHAT IS EASIEST FOR SYSTEM
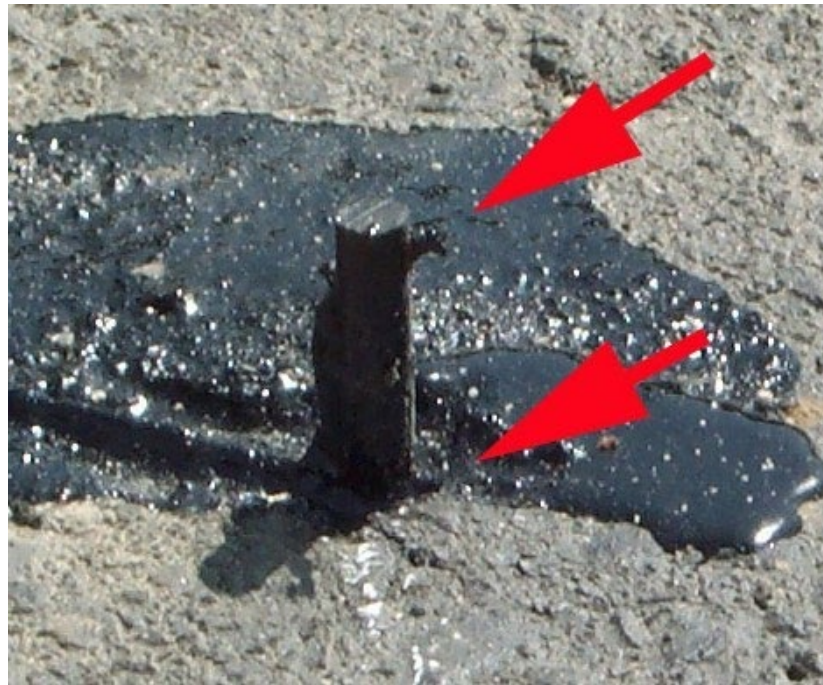
WEIGH-IN-MOTION / CAMERA (DYNAMIC)

COULD BE SPEED
COULD BE AXLE COUNT
COULD BE VEHICLE CLASSIFICATION

DATA RATES

Sample Speed Rate

To define the influence zone curve under T_F and T_R, we recommend a minimum of 30 data point with a much more accurate curve developed with 60 data points.

Data Rates	35mph (60 kph)	75mph (120 kph)
TF: 30 data points	171 S/s	365 S/s
TF: 60 data points	342 S/s	**731 S/s**
TR: 30 data points	64 S/s	136 S/s
TR: 60 data points	127 S/s	227 S/s

HOW IT WORKS: HIGH-SPEED MONITORING

PLATFORM INTERACTIVE DATA HOSTING

Data hosting through Microsoft® Azure that allows:

+ Simple and secure data measurement
+ 24/7 staffed service center
+ Custom alerts and notifications
+ Advanced graphing options

EXTERNAL COMMS

Data transfer from the Core Data Logger to an off-site location can be accomplished by:

+ Hard line communication link
+ Cellular modem
+ Satellite modem

CORE DATA LOGGER

Our industrial-rated Core Data Logger is the essential component that collects, processes, and stores the data from the distributed DAQ nodes.

+ Solid state hard drive
+ Dual network ports
+ Data processing
+ Custom alerts

INTERNAL COMMS & POWER

The communication backbone is standard TCP/IP and the power distribution is 24/48 Vdc. To support this design, we supply the following components:

+ Industrial Ethernet switches
  ▪ Passive Power over Ethernet injection
+ Industrial Ethernet cable
+ Armored Ethernet & power cable
+ Wireless point-to-point comms

DATA TRANSFER

+ **STS-SYNC:** Microsoft® Windows® application to collect data on a defined schedule.
+ **Client Servers:** The Core Data Logger can be configured to push data to a client designated server.

SETUP/CONFIGURATION

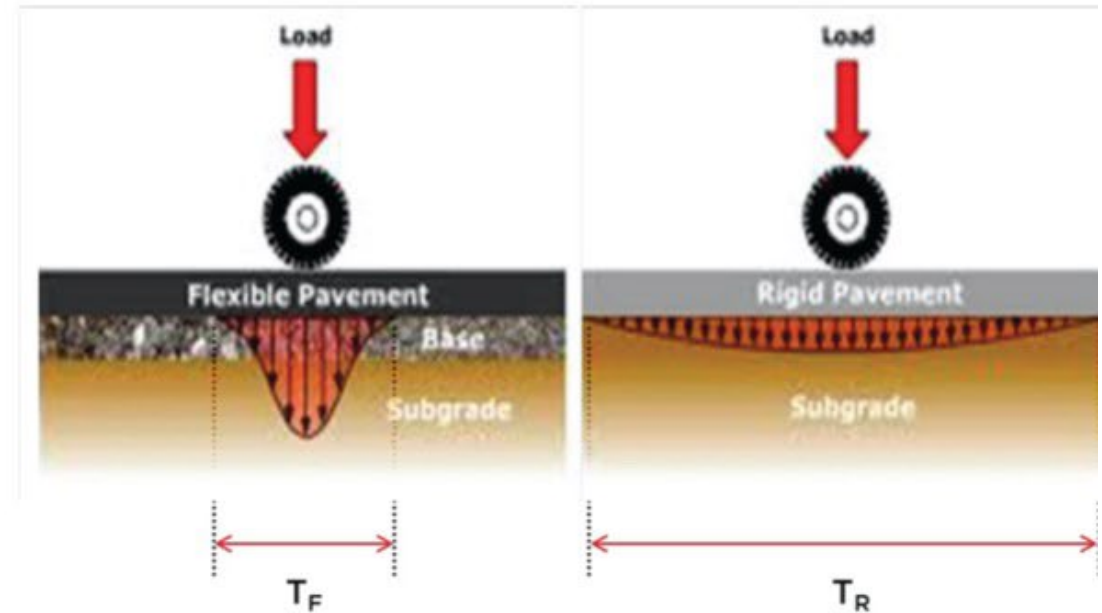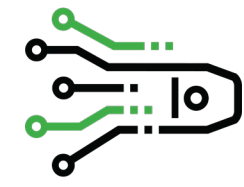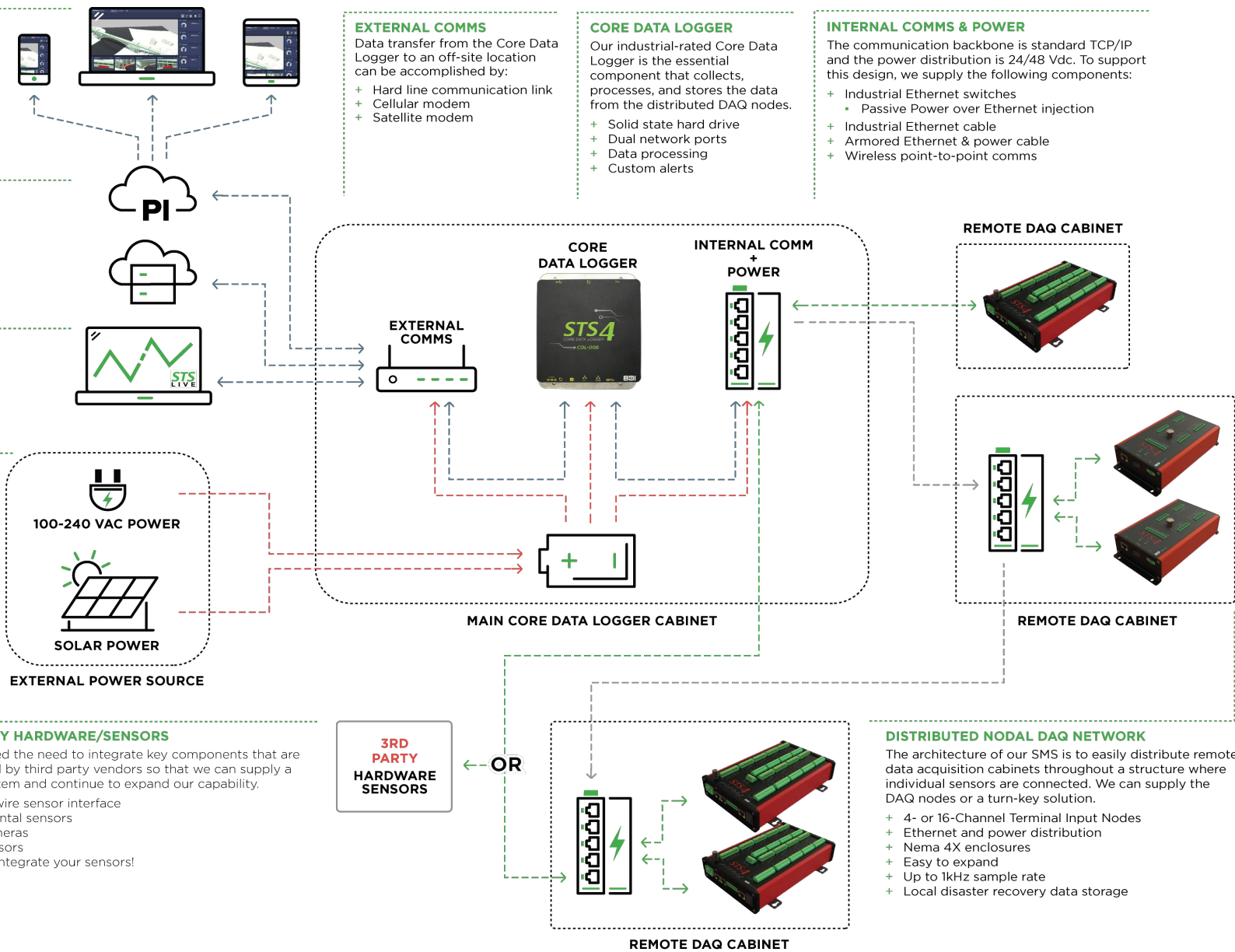+ STS-MONITOR is used for configuring the system, either remotely or through direct on-site connection.
+ Systems can be preconfigured by BDI or by the Client.

POWER

Many solutions are available depending on site require-ments:

+ 90-220 VAC line input
+ Wide range of solar power options
+ UPS battery backup system
+ Remotely monitor the power system with email/SMS alerts directly from the Core Data Logger in the event of a power failure.

THIRD PARTY HARDWARE/SENSORS

BDI recognized the need to integrate key components that are manufactured by third party vendors so that we can supply a complete system and continue to expand our capability.

+ Vibrating wire sensor interface
+ Environmental sensors
+ Digital cameras
+ Digital sensors
+ Ask us to integrate your sensors!

DISTRIBUTED NODAL DAQ NETWORK

The architecture of our SMS is to easily distribute remote data acquisition cabinets throughout a structure where individual sensors are connected. We can supply the DAQ nodes or a turn-key solution.

+ 4- or 16-Channel Terminal Input Nodes
+ Ethernet and power distribution
+ Nema 4X enclosures
+ Easy to expand
+ Up to 1kHz sample rate
+ Local disaster recovery data storage

PI

REMOTE DAQ CABINET

CORE DATA LOGGER

INTERNAL COMM + POWER

EXTERNAL COMMS

STS4

100-240 VAC POWER

SOLAR POWER

EXTERNAL POWER SOURCE

MAIN CORE DATA LOGGER CABINET

REMOTE DAQ CABINET

3RD PARTY HARDWARE SENSORS

OR

REMOTE DAQ CABINET

STRUCTURAL MONITORING SYSTEM (SMS)
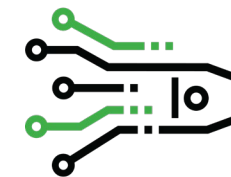
4- OR 16-CHANNEL TERMINAL NODES

+ Terminal Inputs: 4 Analog Sensors + 4 Temps
+ 0 to +5 Vdc and +15 Vdc excitation
+ +15 Vdc Power Supply
+ 24-bit ADC with 1 kHz sample rate per channel
+ Configure Channels through STS-LIVE
+ Temperature Range: -40 to +85 °C

MONITORING ACCESSORIES

+ Intel® Atom™ processor E3800 family
+ DDR3L SDRAM up to 8GB
+ 128GB SATA II 2.5" SSD
+ Dual Gigabit LAN port
+ Programmable Watchdog Timer
+ One Selectable RS232/422/485 port (Optional)
+ Temperature Range: -40°C to +85°C

MONITORING ACCESSORIES

+ Solar/AC battery backed power
+ Systems
+ Enclosures
+ Power/Communication cables
+ Wireless communication
+ Third party sensors/systems integration
+ Cellular/Satellite/Hard Line communications
+ Many more, please inquire

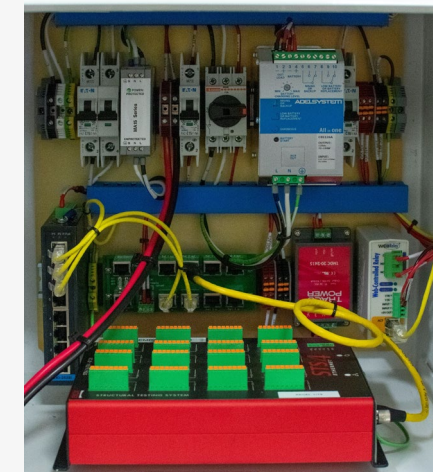# DATA ACQUISITION: 4- & 16-CH TERMINAL NODES

+ Terminal Inputs: 4 Analog Sensors + 4 Temps

+ 0 to +5 Vdc and +15 Vdc excitation

+ +15 Vdc Power Supply

+ 24-bit ADC with 1 kHz sample rate per channel

+ Configure Channels through STS-LIVE

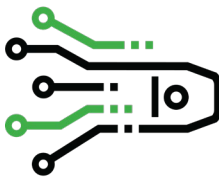+ Temperature Range: -40 to +85 °C

DATA ACQUISITION: CORE DATA LOGGER

+ Intel® Atom™ processor E3800 family

+ DDR3L SDRAM up to 8GB

+ 128GB SATA II 2.5" SSD

+ Dual Gigabit LAN port

+ Programmable Watchdog Timer

+ One Selectable RS232/422/485 port (Optional)

+ Temperature Range: -40 to +85°C

DATA COLLECTION SOFTWARE　NO PROGRAMMING!

STS-MONITOR: DATA ACQUISITION SOFTWARE HAS BEEN DESIGNED WITH ALL THE FEATURES REQUIRED TO EVALUATE THE QUALITY OF THE DATA COLLECTED QUICKLY AND UNDER THE PRESSURE OF ON-SITE FIELD PROJECTS!

+ Automatic recognition of all hardware!
  - Setup alias file to apply all sensor settings

+ Real-time data display
  - Group sensors within data display
  - Range of filtering options
  - Convert data to frequency domain

+ Virtual Sensors
  - Create virtual sensors using mathematical functions

+ Monitoring Configuration
  - Capture event based data blocks
  - Rainflow histogram data (fatigue analysis)
  - Historic trend data

+ Custom LabView programming
  - Open source STS-CORE software for clients to develop custom programs
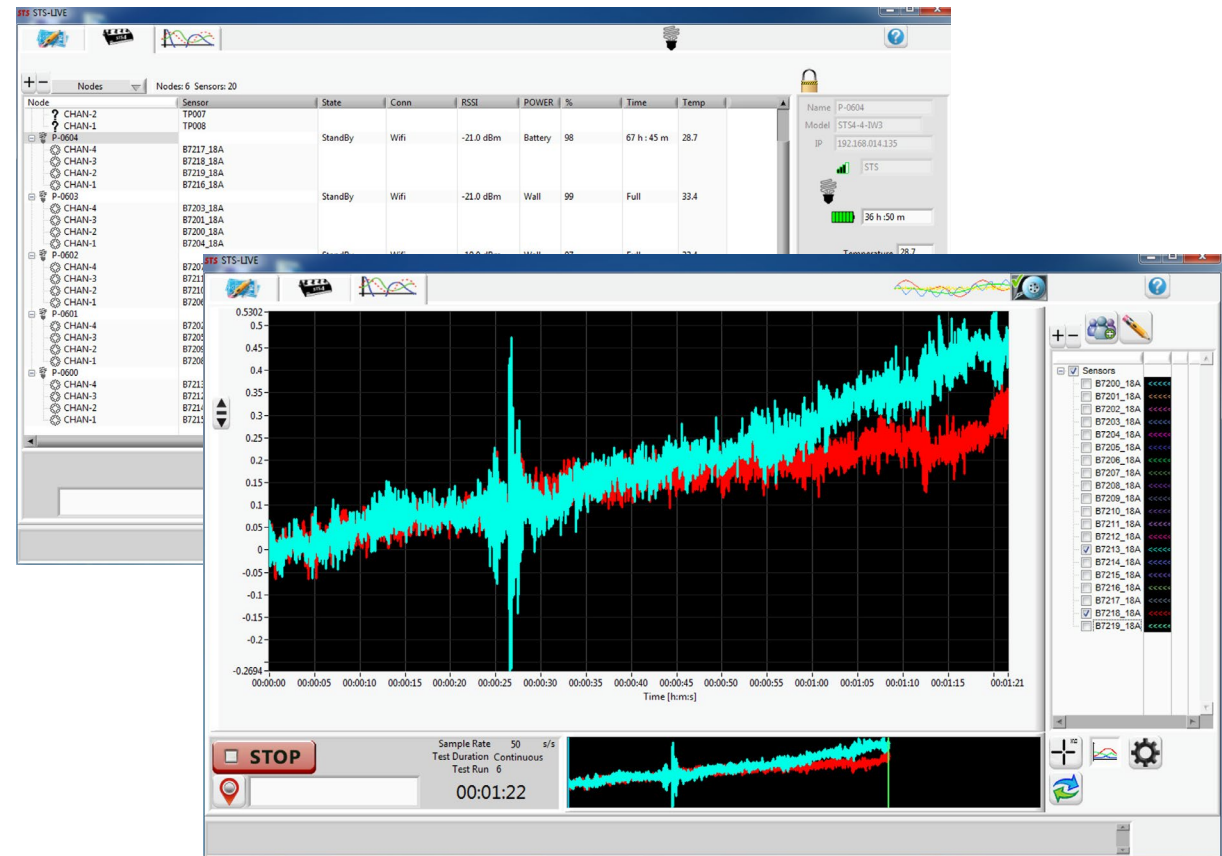 - BDI can develop custom applications for our clients
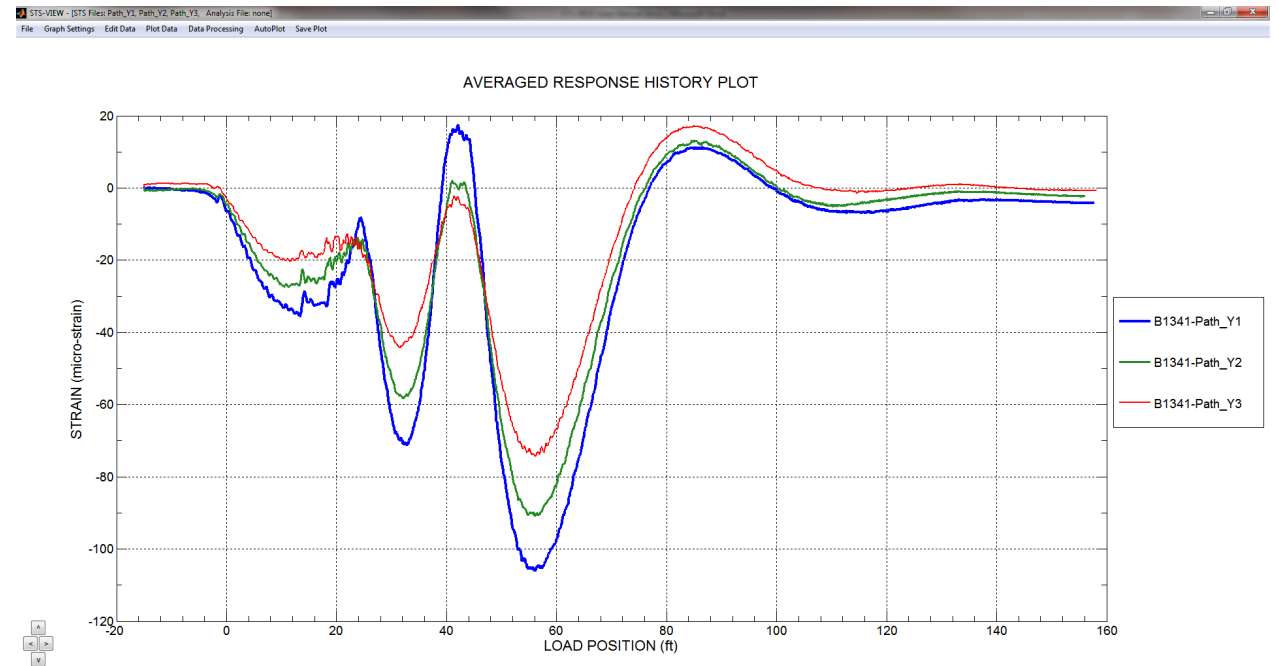
DATA PROCESSING SOFTWARE   MENU DRIVEN!

STS-VIEW: DATA ACQUISITION SOFTWARE HAS BEEN DESIGNED WITH ALL THE FEATURES REQUIRED TO EVALUATE THE QUALITY OF THE DATA COLLECTED QUICKLY AND UNDER THE PRESSURE OF ON-SITE FIELD PROJECTS!

+ Compatible data files
  - Works with BDI *.tdms & *.dat data file structure
  - Compatible with Campbell Scientific data files

+ Data display options
  - Response, curvature, neutral axis plots
  - Group sensors for averaged range calculation
  - Range of filtering & decimation options
  - Convert data to frequency domain

+ Input Options
  - Load finite element analysis results for direct
  - Graphical comparison with collected data

+ Extract Data
  - Excel spreadsheet
  - Text file
  - Max/Min value extraction

+ Auto Plot Graphs
  - Generate graphs for reports

DATA MANAGEMENT AND VISUALIZATION

- Client monitoring system portal
- Microsoft AZURE cloud-based hosting service
  - Enterprise level security
  - 99.99% uptime
  - Multiple layers of redundant backup
- 24/7/365 Helpdesk support

Features:
- Scalable architecture
- Drag-and-drop setup and configuration to minimize site development time
- Sensor agnostic
- Fully customizable
- Automated & manual data compatible

QUALITY ASSURANCE / DOCUMENTATION
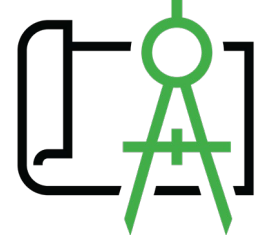
DOCUMENT, DOCUMENT, DOCUMENT

QUALITY CONTROL FABRICATION AND HOOK-UP SHEET

BDI RAW DATA. REFINED RESULTS.

DYNAMIC ASG
ASPHALT STRAIN GAGE 6X8"

Gage ID:_____
Lead Length:_____

NOTE: MANUAL READINGS TAKEN USING VISHAY P-3500.   GF = 2.00   BALANCE = 500

FABRICATION

GAGE RESISTANCE :_____

INITIAL READING AFTER WIRING GAGE :_____

SHORT TO SHIELD :_____

TENSION = _____ IN READING

READING AFTER J-COAT :_____

READING AFTER ALL PROTECTION :_____
  (after butyl rubber and heat shrink)

DATE :_____   WHO :_____

SHORT TO SHIELD :_____

COMMENTS:_____

COLOR	BRIDGE	P-3500
Red	$V_{EX}+$	P+
Black	$V_{EX}-$	P-
White	$V_{CH}-$	S-

CALIBRATION

EXCITATION :_____   CAL FACTOR :_____ ue/mV/

DATE :_____   WHO :_____

FINAL READING AFTER CALIBRATION AND DIPPING :_____

INSTALLATION

NOTE: MANUAL READINGS TAKEN USING VISHAY P-3500.
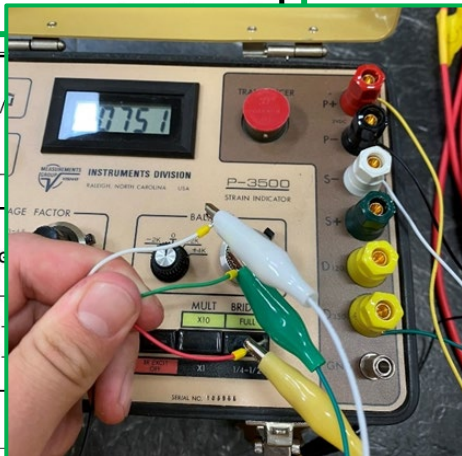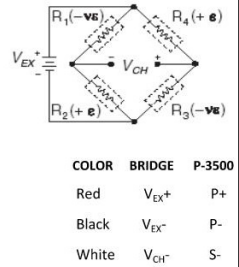
LOCATION :_____   X:_____

DATE :_____   READING :_____   EVENT :

DATE :_____   READING :_____   EVENT :

HOOKUP TO SYSTEM

SPU :_____   CHANNEL :_____

DATE :_____   READING :_____   EVENT :_____

QC/QA INSTALLATION AND HOOK-UP SHEET

BDI RAW DATA. REFINED RESULTS.

EARTH PRESSURE CELLS (EPC)

Gage ID:_____
Lead Length:_____

NOTE: MANUAL READINGS TAKEN USING HANDHELD READOUT

TYPE - 0-5 VOLT OUTPUT OVER 0.35MPA (50 PSI)

PRE-INSTALLATION

DATE :_____   WHO :_____   CAL FACTOR :_____

READING PRIOR TO INSTALLATION :_____

INSTALLATION

NOTE: MANUAL READINGS TAKEN USING MANUAL READOUT

LOCATION :_____   X:_____   Y:_____   Z:_____

DATE :_____   READING :_____   EVENT :_____

COMMENTS:_____

DATE :_____   READING :_____   EVENT :_____

COMMENTS:_____

DATE :_____   READING :_____   EVENT :_____

COMMENTS:_____

DATE :_____   READING :_____   EVENT :_____

HOOKUP TO SYSTEM

SPU :_____   CHANNEL :_____

DATE :_____   READING :_____   EVENT :_____
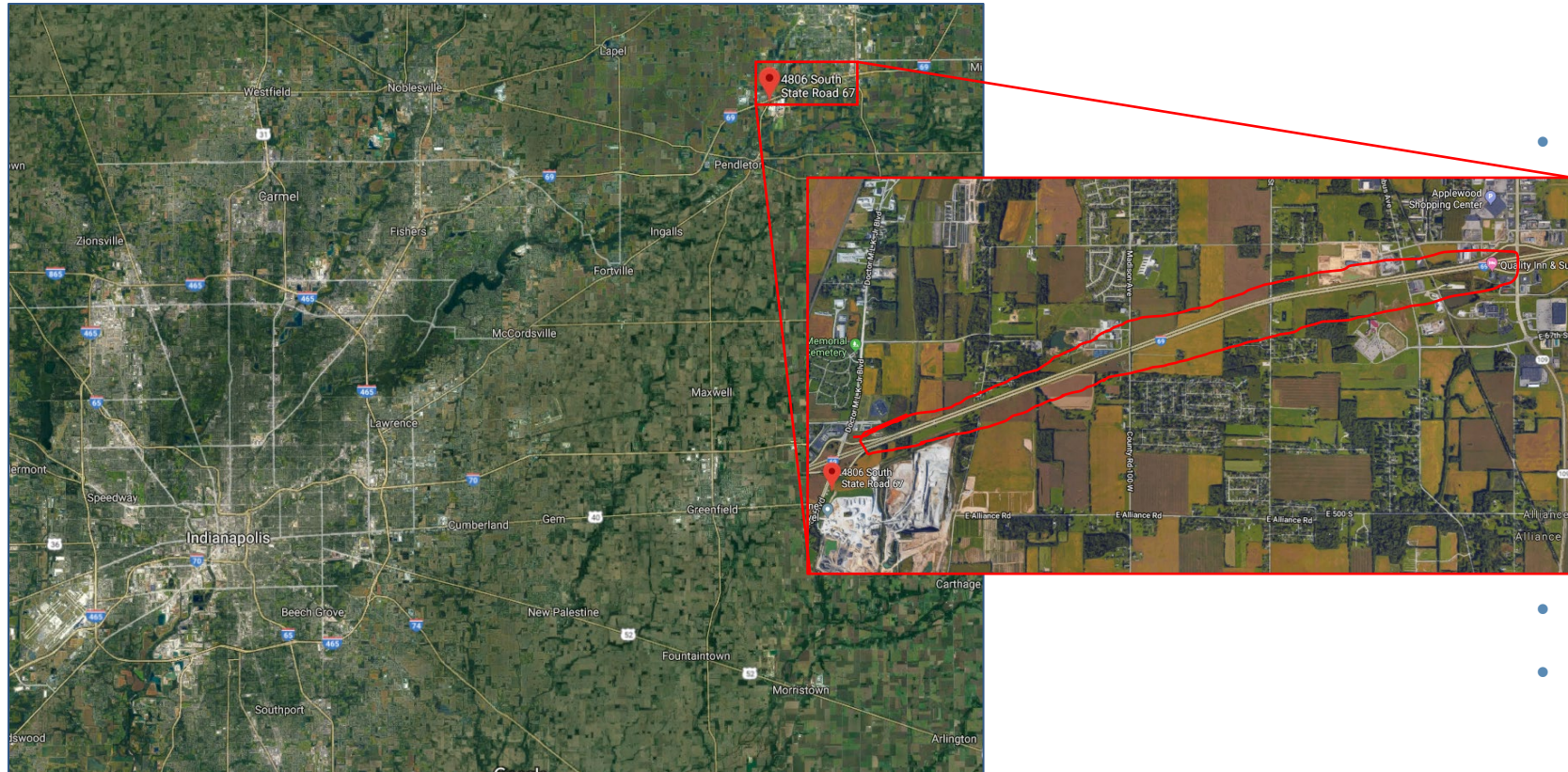
COMMENTS:_____

DATE :_____   READING :_____   EVENT :_____

COMMENTS:_____

CASE STUDIES

I-69 PAVEMENT, INDOT 22 TEST SECTIONS

- Bid on Existing Specification
  - 22 Flexible Pavement Test Sections
  - 144 Asphalt Strain Gages **(+44)**
  - 48 Temperature Sensors
  - 78 Earth Pressure Cells
  - 10 Soil Strain Gages
  - 44 Moisture Gages
  - Portable ADAS
- Installation and Oversight
- Training, Load Testing and Support

PM for Geocomp on this project

CASE STUDIES

I-69 PAVEMENT, INDOT 22 TEST SECTIONS

- Penalty / Bonus System - $5,000/sensor type/<u>test section</u>(*) not meeting minimum success rates

Sensor	Total	Min	Plus 1	Plus 2	Plus 3
ASG	6	4	$1,000	$2,500	
TC	2	1	$2,500		
EPC base	2	1	$2,500		
EPC CSS	3	2	$2,500		
DSG $_{total}$	10	7	$1,000	$1,500	$2,500
MG	2	1	$2,500		
VSG	2	1	$2,500		

CASE STUDIES

HNL AIRPORT TAXIWAY

REMOTE STAND-ALONE SYSTEM

- Specification Development
  - One Cold Planed Flexible Test Section
  - 56 Asphalt Strain Gages
  - 2 Temperature Trees
  - Remote System Power
  - Remote System Communication
  - Operation and Maintenance Manual
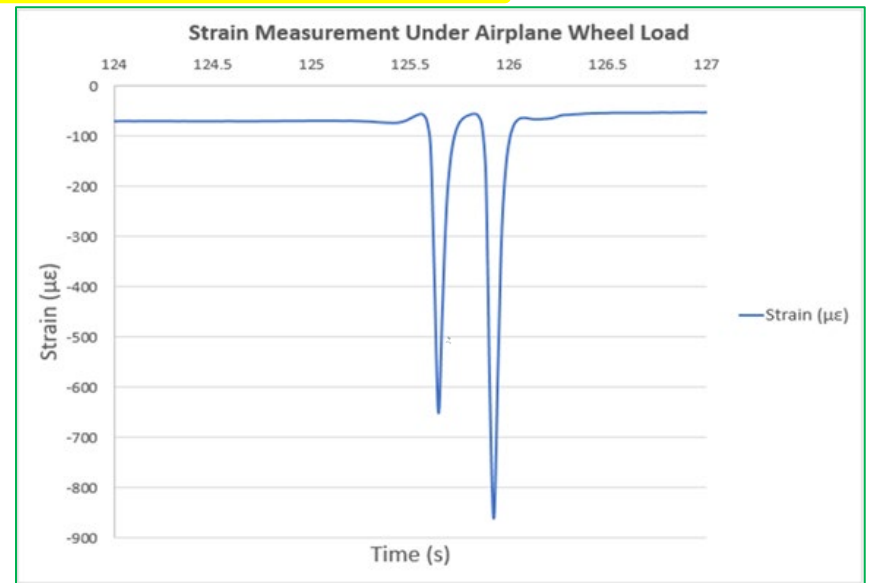- Installation and Commissioning
- Training and Support

PM for Geocomp on this project

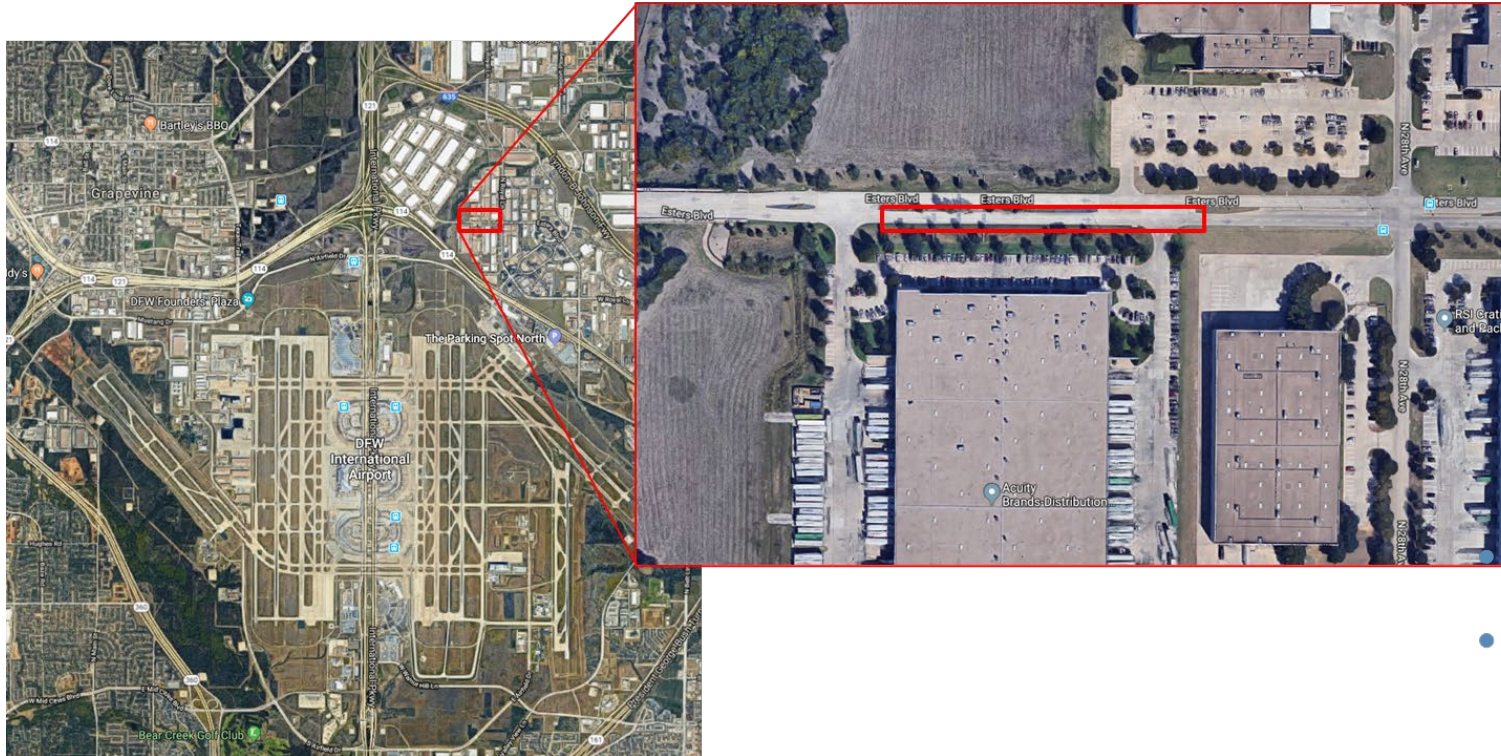# CASE STUDIES

HNL AIRPORT TAXIWAY

SENSOR TRIGGER DATA COLLECTION
SENSOR TRIGGER CAMERA IMAGE CAPTURE

CASE STUDIES

## DFW SERVICE ROADS

REMOTE STAND-ALONE SYSTEM

- Specification Development
  - Three Rigid Pavement Test Sections
  - 48 Concrete Strain Gages
  - SG Temperature Sensors
  - 12 Earth Pressure Cells
  - 12 Soil Compression Gages
  - Remote System Power/Communication
  - Operation and Maintenance Manual
- Installation and Commissioning
- Training, Load Testing and Support

PM for Geocomp on this project

CASE STUDIES

DFW SERVICE ROADS

CASE STUDIES

GDOT GEOSYNTHETIC TEST PROGRAM – 18 TEST SECTIONS
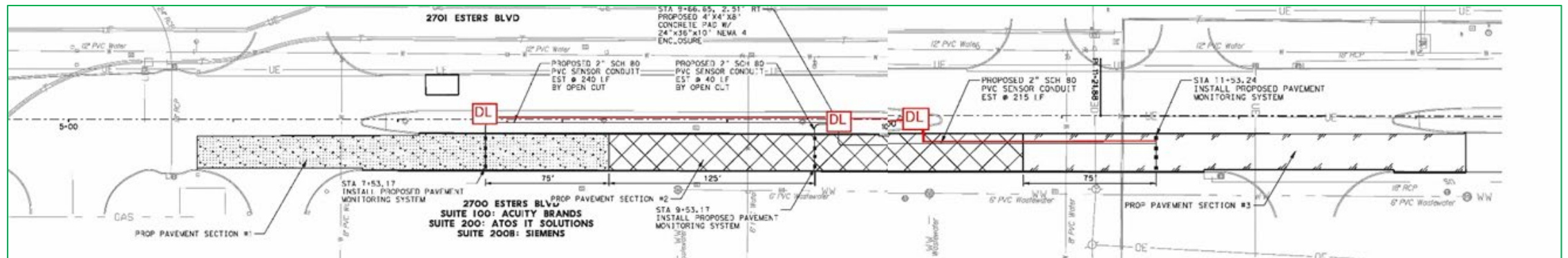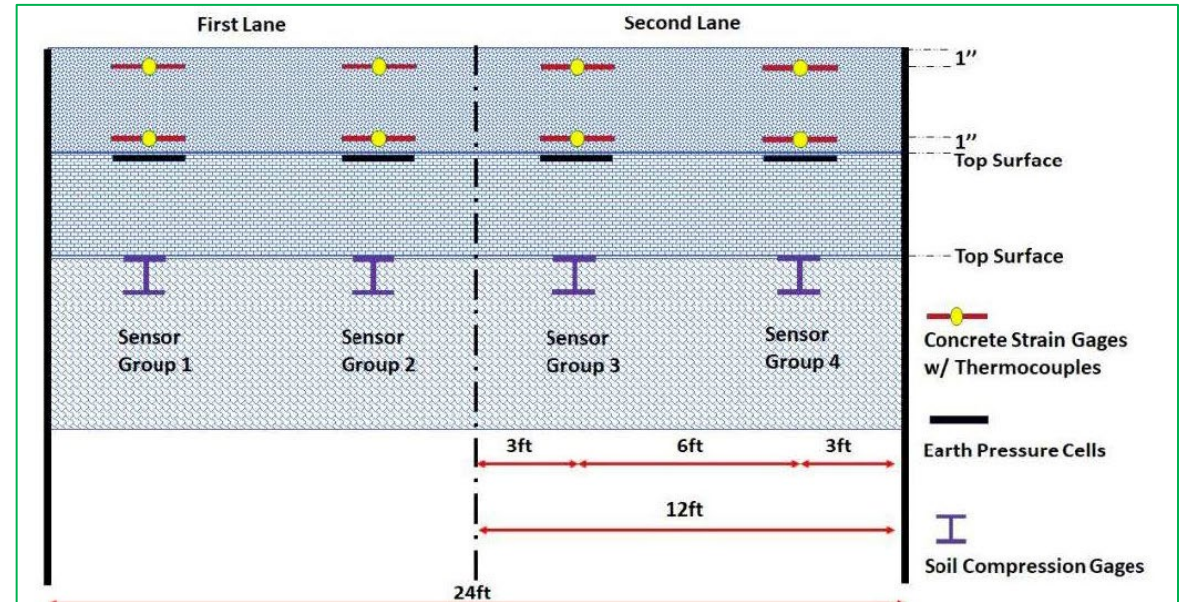
CASE STUDIES

GDOT GEOSYNTHETIC TEST PROGRAM – 18 TEST SECTIONS

EVENT TRIGGERED
VEHICLE CLASSIFICATION

NEW TECHNOLOGIES

FBG STRAIN MEASUREMENTS
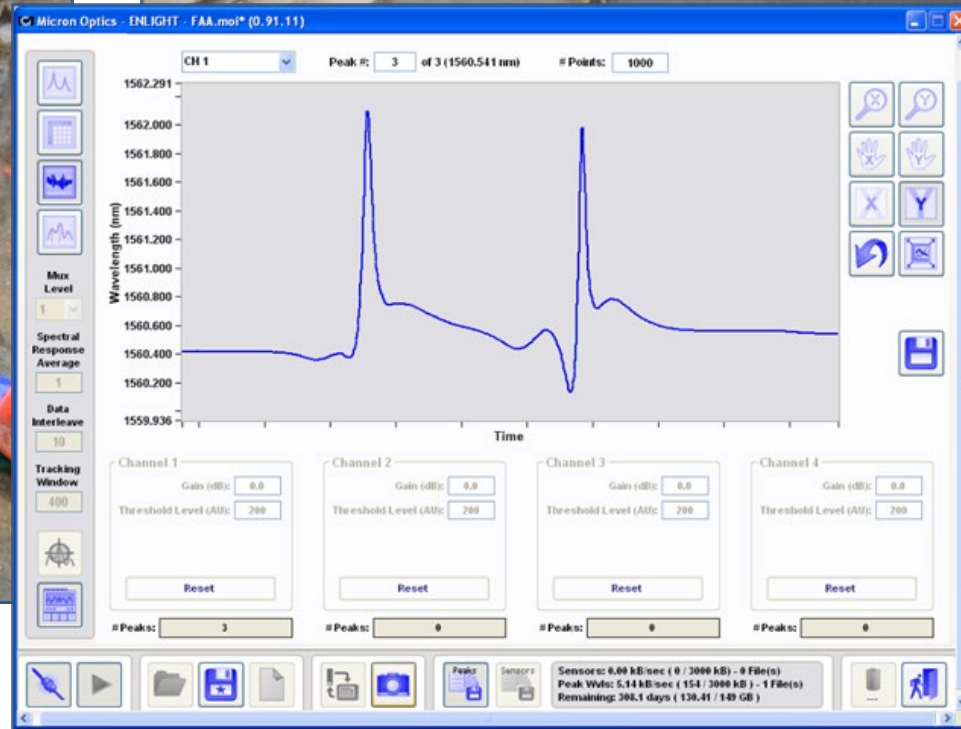
NEW TECHNOLOGIES

FBG EMBEDDED GEOSYNTHETIC
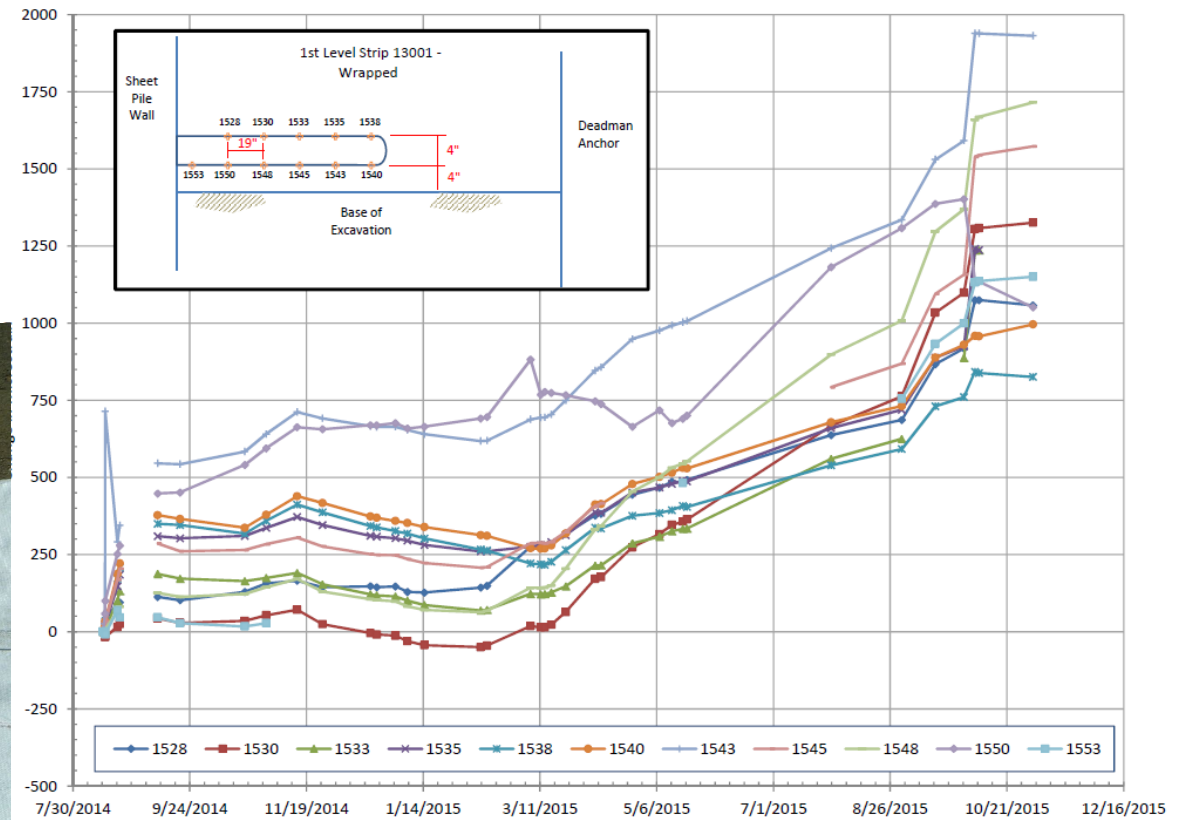
NEW TECHNOLOGIES

DISTRIBUTED STRAIN AND TEMPERATURE FIBER OPTICS

1000 Sensor System
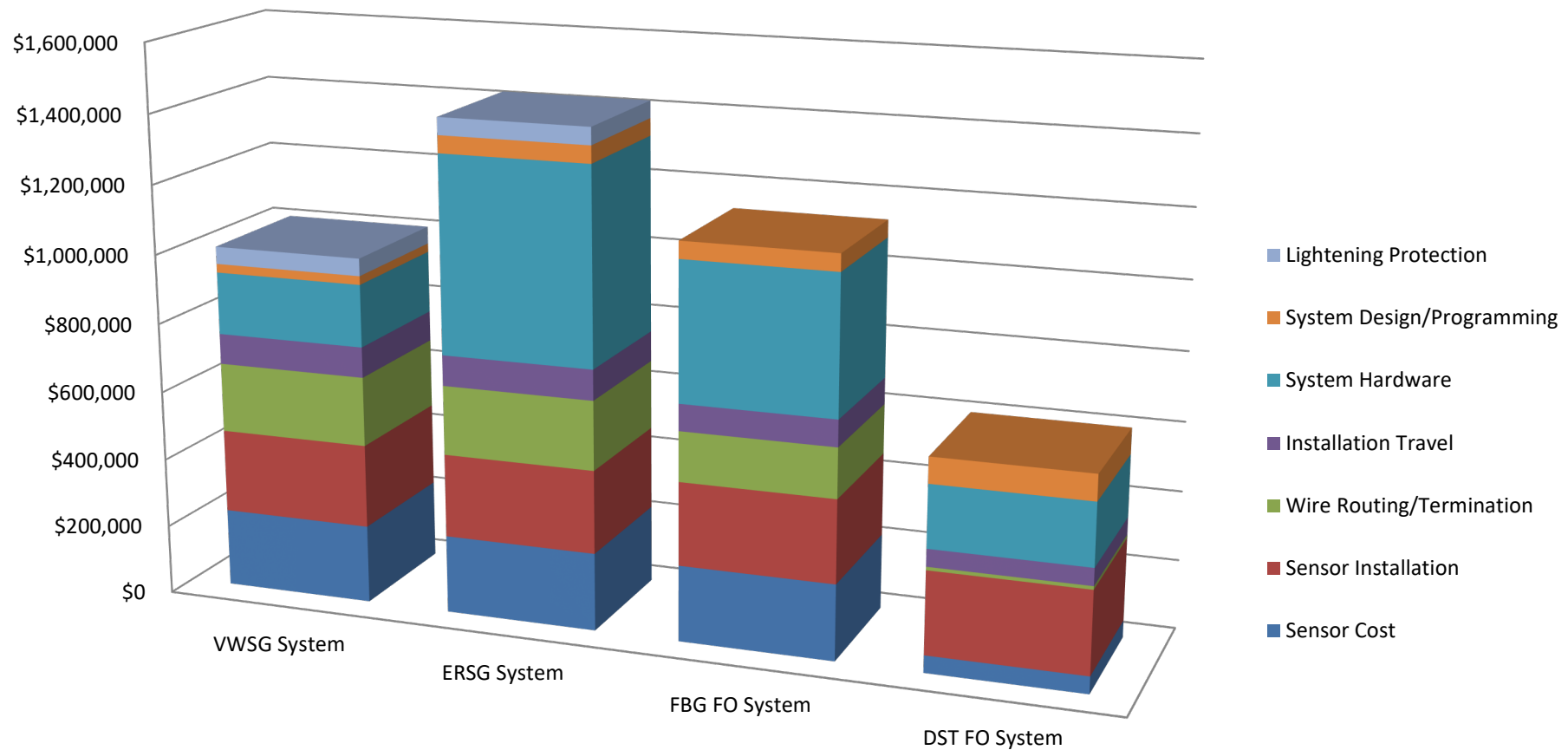
NEW TECHNOLOGIES

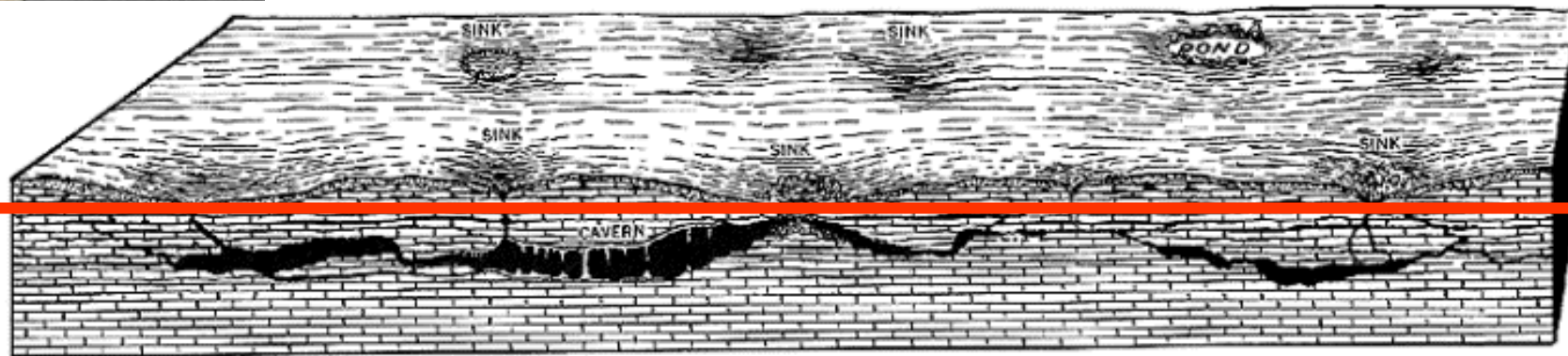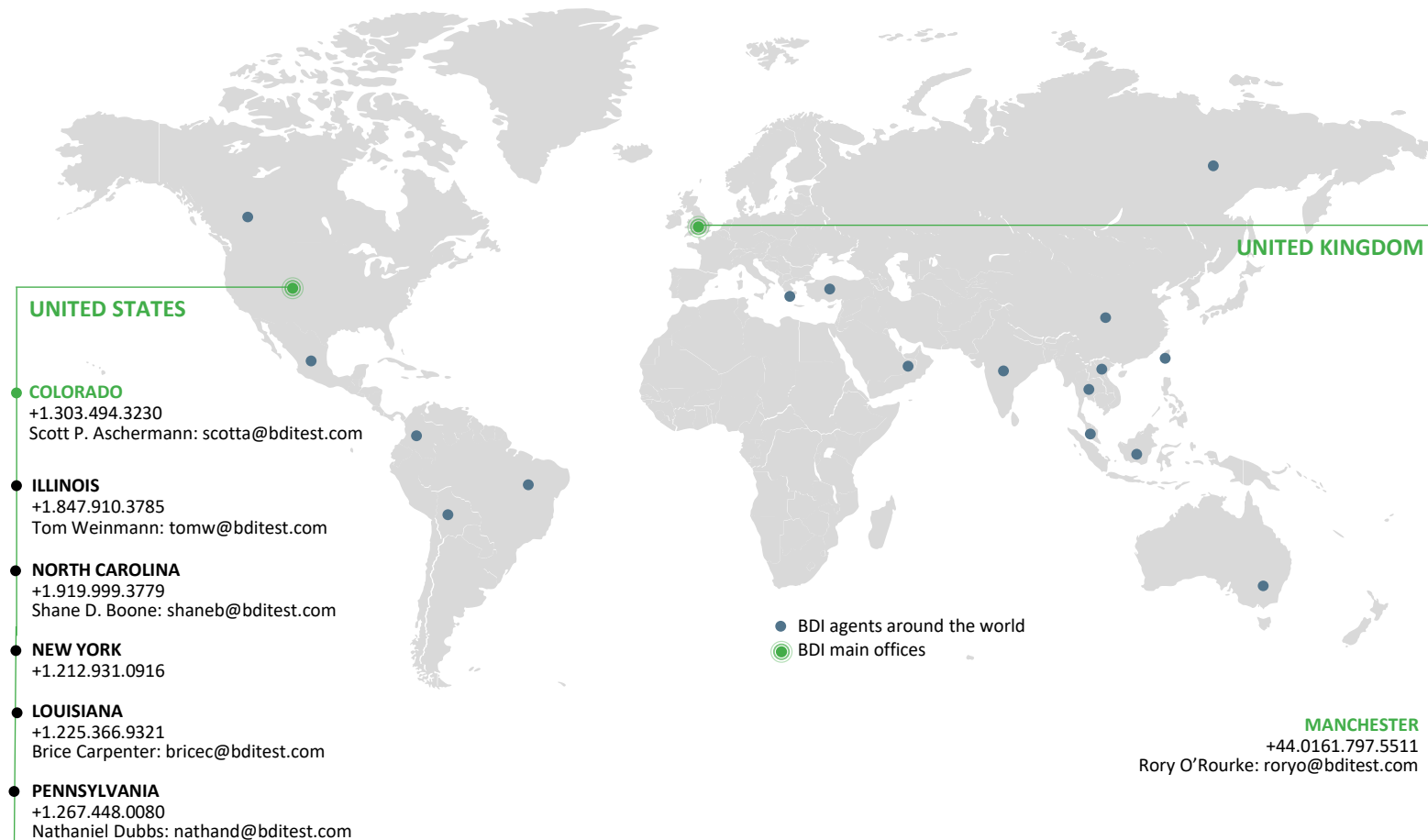## DISTRIBUTED STRAIN AND TEMPERATURE (DST FO)

Sinks and their relation to solution cavities beneath the surface.

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THANK YOU

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