

# DRIVEN CONCRETE PILE FOUNDATION MONITORING WITH EMBEDDED DATA COLLECTOR SYSTEM

Presented By: Paul Steinman

Based On An Evaluation By:

Rodrigo Herrera, Larry Jones, Peter Lai

FTBA/FDOT Construction Conference  
February 23, 2010



# Embedded Data Collector

- Alternate method of pile driving monitoring was investigated through FDOT sponsored research
- University of Florida's Final report
  - Theory
  - First generation hardware and software
  - Construction Project BB349
- The UF/FDOT technology was licensed for further development



# Introduction

- Majority of Florida bridges are supported on deep foundations.
- Most common deep foundation:  
Precast Prestressed Concrete piles.
- All test piles and some production piles are monitored with systems involving strain gauges and accelerometers attached at the top of the pile.



## Current FDOT Practice

- Test Pile Program
  - Analysis using data obtained from top of the pile during driving.
- Based on the above information, Production Pile Lengths are estimated and Pile Driving Criteria are established.
- Installation of Production Piles.



## What is Embedded Data Collector

- Two instrumentation levels embedded at top and bottom of the pile.
- Wireless data transfer
- By adding extra instrumentation at the pile tip in addition to the one at pile head more data could be available that is not otherwise obtainable.
- Estimates soil damping for every blow during driving
- Real-time estimates of static resistances, i.e., side, tip and total.
- Antenna connects to laptop PC



**Top Assembly**

**Tip Assembly**

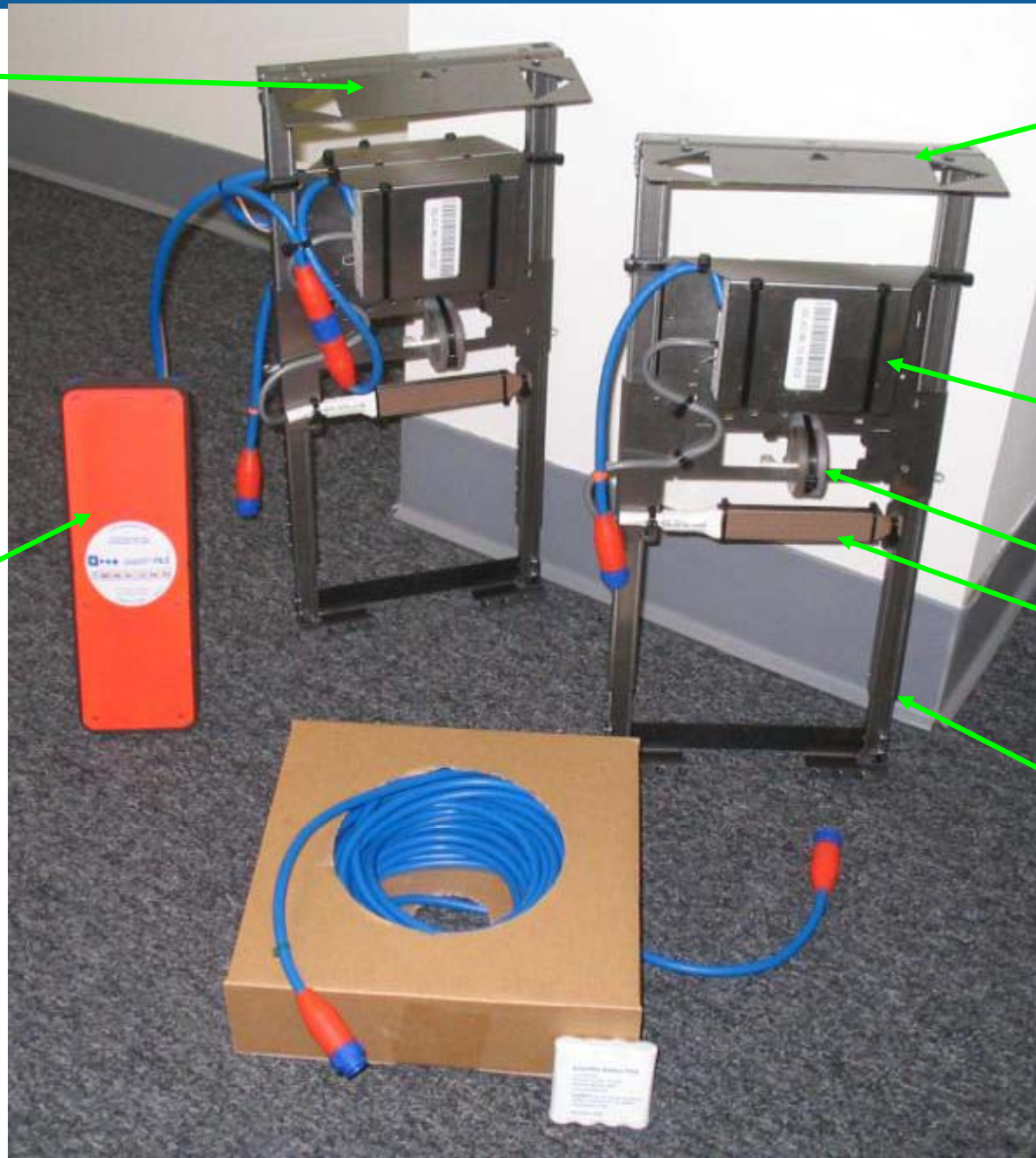
**Electronics Module**

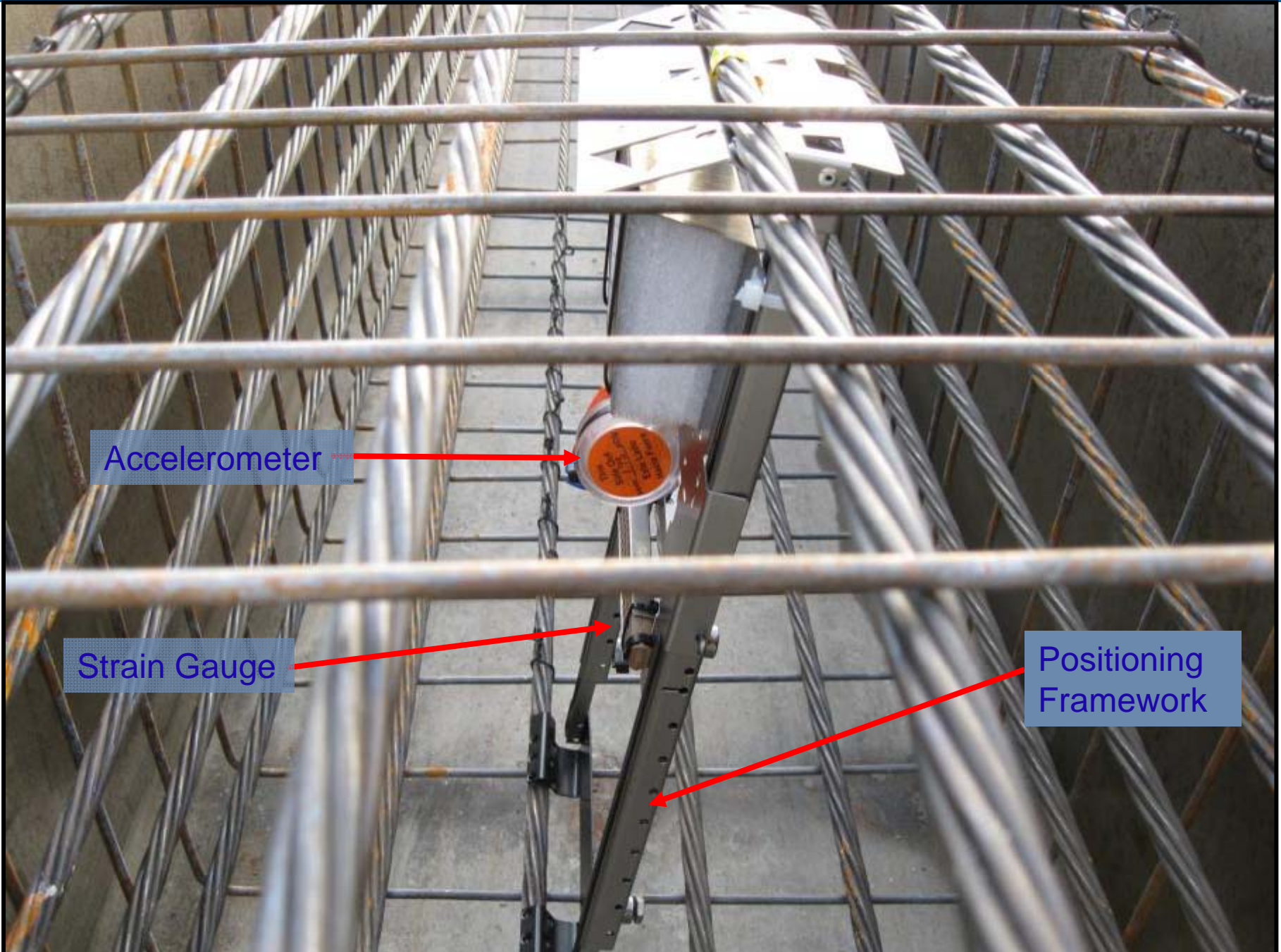
**Accelerometer**

**Strain Gauge**

**Positioning Framework**

**Wireless Interface  
(Dataport)**





Accelerometer

Strain Gauge

Positioning Framework



Accelerometer

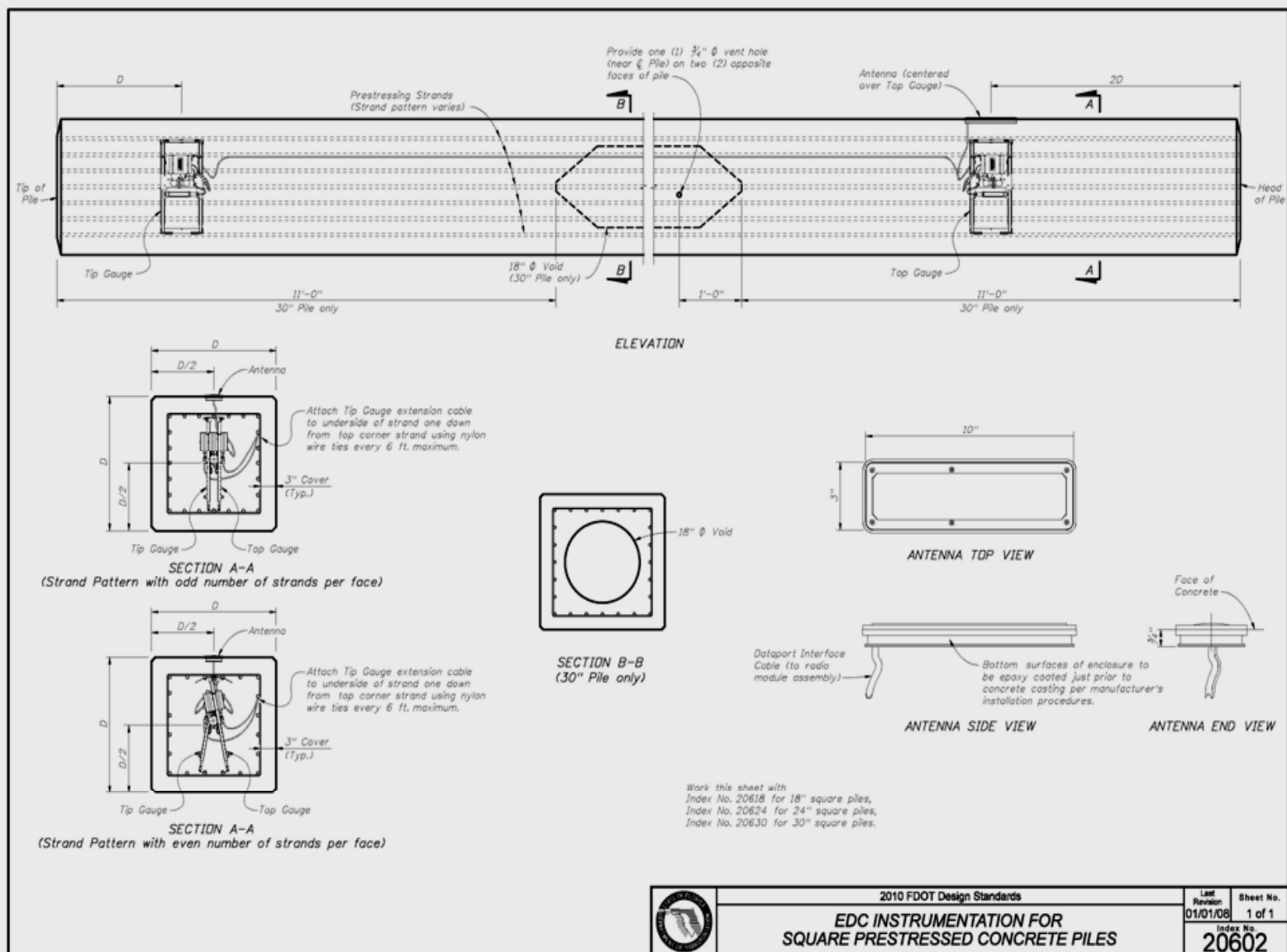
Positioning Framework

Strain Gauge –  
centered in pile core

# Embedded Data Collector

FDOT Design Standard Index 20602

Instruments cast at Pile Top and Tip

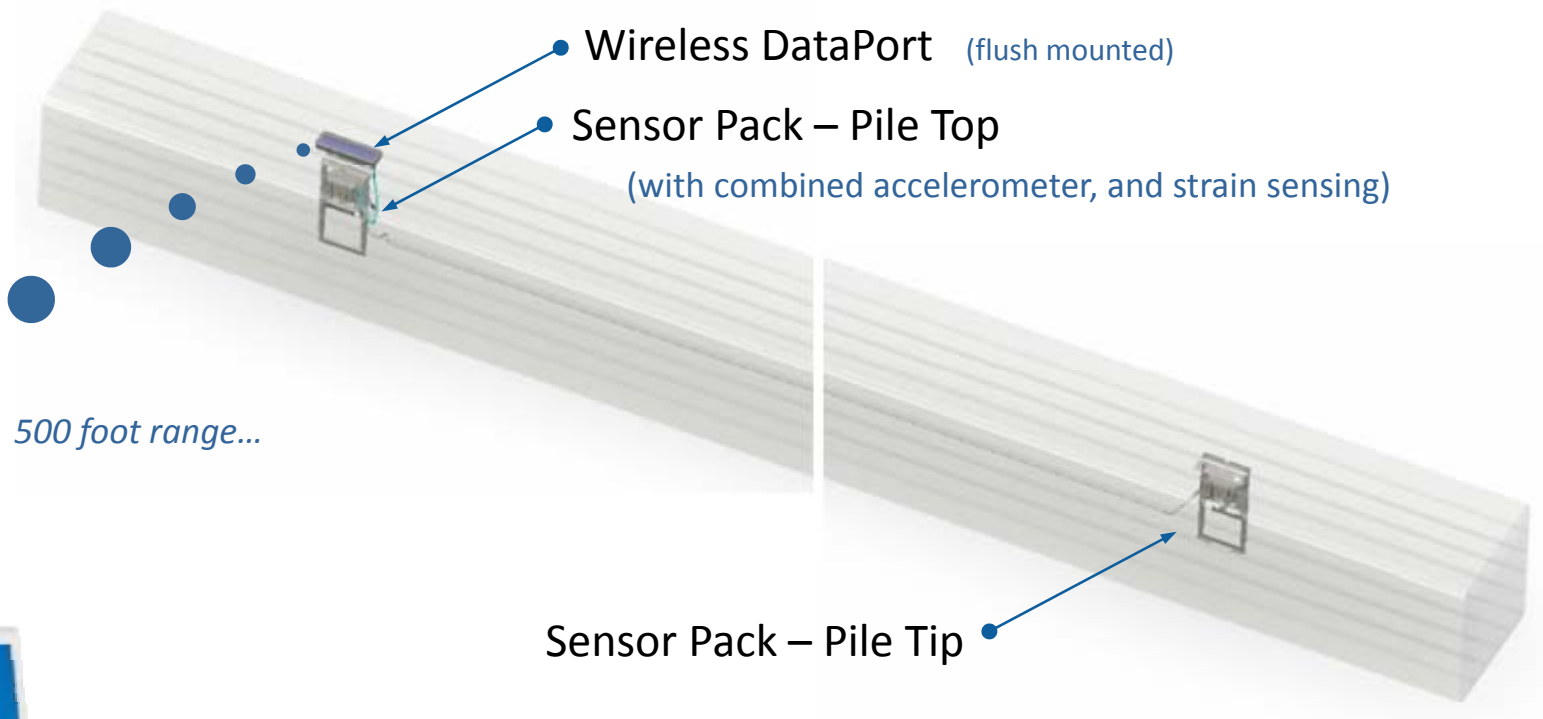


2010 FDOT Design Standards

**EDC INSTRUMENTATION FOR  
 SQUARE PRESTRESSED CONCRETE PILES**

|                           |           |
|---------------------------|-----------|
| Last Revision             | Sheet No. |
| 01/01/08                  | 1 of 1    |
| Index No.<br><b>20602</b> |           |

# The Current **EDC** System



Engineering Workstation

configurable up to 3 SensorPacks total/system

*Universal Installation Bracket*



## Implementation Guidelines

- Temporary Design Bulletin (C09-04)/DCE Memo 14-09 June 11, 2009
- The above mandate that for projects let after January 1, 2010 have 100% EDC testing required whether test piles are or are not required to determine final pile length



## 455 Special Provisions

EDC implementation:

- SP 4550510A: All Bridge Projects with square prestressed concrete pile foundation, with test piles
- SP 4550510B: All Bridge Projects with square prestressed concrete pile foundation, without test piles



## 455 Special Provisions

EDC implementation: SP 4550510A:

455-5.11.1: Notify the Engineer two work days prior to placement of piles within the template and at least one work day prior to driving piles. Do not drive piles without the presence of the Engineer.

- The Engineer will determine pile capacity of the Test Piles based on the results of Dynamic Load Tests using externally mounted instruments. Allow the Engineer one work day after driving the dynamic load tested pile to analyze the data and determine the damping value for the EDC equipment.
- After determining the appropriate damping value, the Engineer will determine the capacity of the production piles for each pier or bent based on EDC equipment...



## EDC implementation: SP 4550510A: (contd)

- If the EDC does not perform to the satisfaction of the Engineer due to actions of the Contractor, engage a Specialty Engineer to perform Dynamic Load Testing of the pile installation at no additional cost to the Department. Set Dynamic Load Test equipment to the damping value provided by the Engineer prior to driving the production pile.
- If the Engineer requires an additional Dynamic Load test for comparison purposes on piles with a properly functioning EDC, the Contractor will be paid an additional Dynamic Load Test. If the Engineer directs the Contractor to engage a specialty engineer to perform Dynamic Load Tests on a pile with a properly functioning EDC, the Specialty Engineer will be paid for as Unforeseeable Work.
- 455-12.1 Data collection from EDCs will be the responsibility of the Department



# EDC Evaluation

## Phase 1: Compare EDC to present technologies

- All the data is submitted to the State Structures Design Office and analyzed by the State Geotechnical Engineer 's Office.
- Data is analyzed for robustness of instrumentation
- Data is compared to the existing technologies
- The purported benefits of two levels of instrumentation is being evaluated



## EDC EVALUATION- Phase II - Comparison with Instrumented Static Load Tests

The anticipated outcomes of EDC Phase II research are:

- Evaluation of EDC estimates of static resistance when compared to static load tests
- Evaluation of EDC pile side and tip static and dynamic resistances
- Development of LRFD resistance factors for EDC pile monitoring
- Using EDC data in combination with in-situ tests and testing to improve pile freeze predictions.
- Managed by Structures Design Office



# Current Database

## State Structures Design Office (State Geotechnical Engineer's Office)

| Database Files        |        |
|-----------------------|--------|
| Bridge Sites          | 79     |
| Analyzed Blows        | 276020 |
| Analyzed Piles        | 203    |
| Total Number of Piles | 245    |
| Re-Strikes            | 56     |



## Present Plan to Evaluate the Following:

- EDC costs will be partially offset by efficiencies from using an increased resistance factor
- Speed of construction
- Reduce Pile Driving Claims
- Reduced Need for Verification Testing on Design-Build Projects: Pile Capacity is verifiable without the normal verification testing associated with D/B.
- Safety



## Present Plan to Evaluate the Following (Contd):

- For projects with predetermined pile lengths, there will be more efficiency in pile installation as driving operations will not need to be interrupted for casting of production piles
- The Department will be monitoring and analyzing pile lengths and EDC cost to determine if there is a net savings or benefit to the Department.



# FDOT's Vision - Long Term Monitoring



## Structural monitoring

- *Normal use*
- *Corrosion*
- *Extreme weather*
- *Hurricane*
- *Ship impact*
- *Earthquake*
- *Scour*

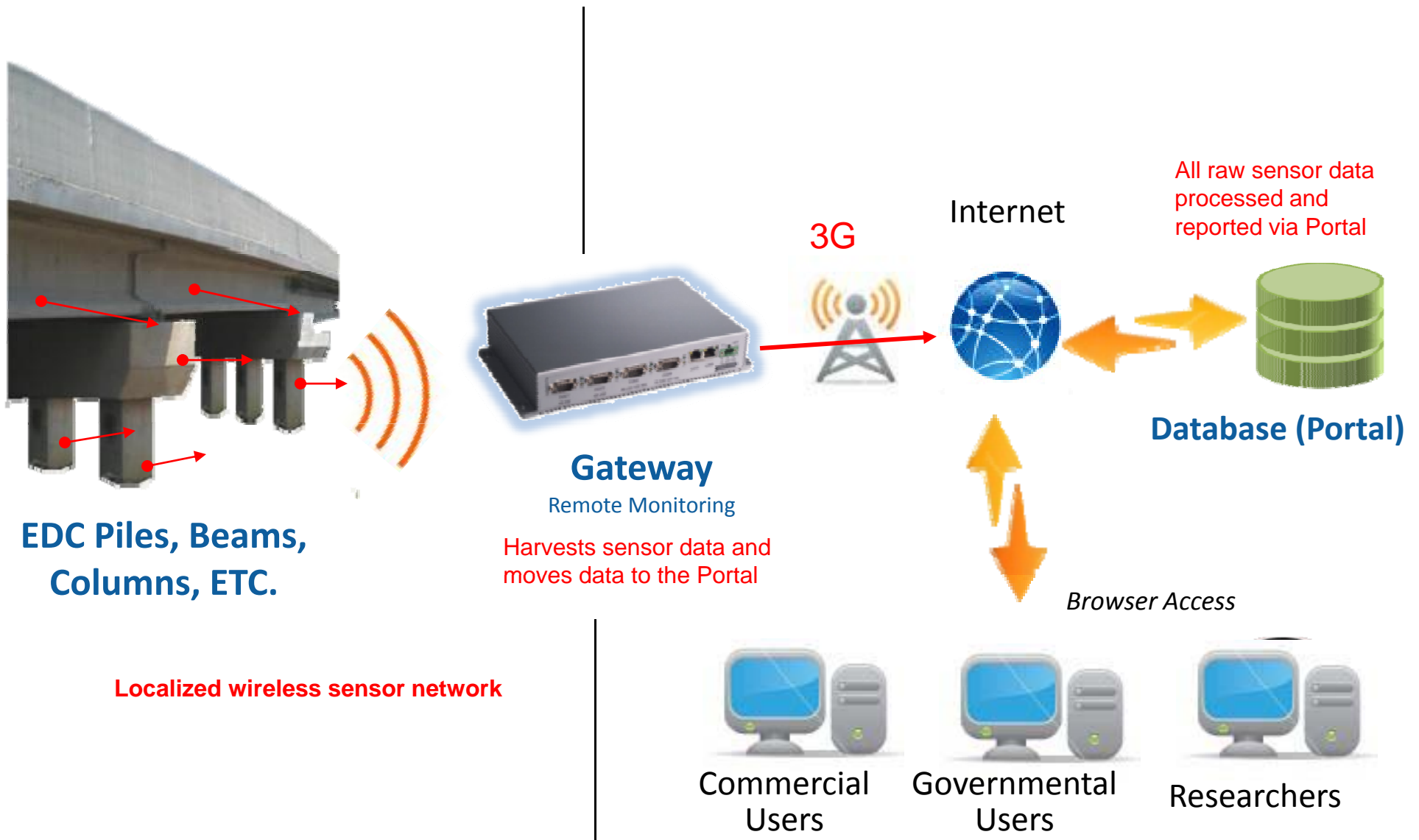


# FDOT's Long Term Monitoring Vision

- FDOT's Vision is to monitor stresses in the foundations and other structural elements when the bridge is in-service.
  - Assist the routine bridge inspection performed by FDOT.
  - Be able to remotely monitor stresses when over-weight vehicles are permitted to use state highway
  - Be able to monitor stresses on bridges in attempt to target enforcement relation to over-weight vehicles similar to Virtual Weigh-in-Motion.



# Remote Monitoring - System Elements



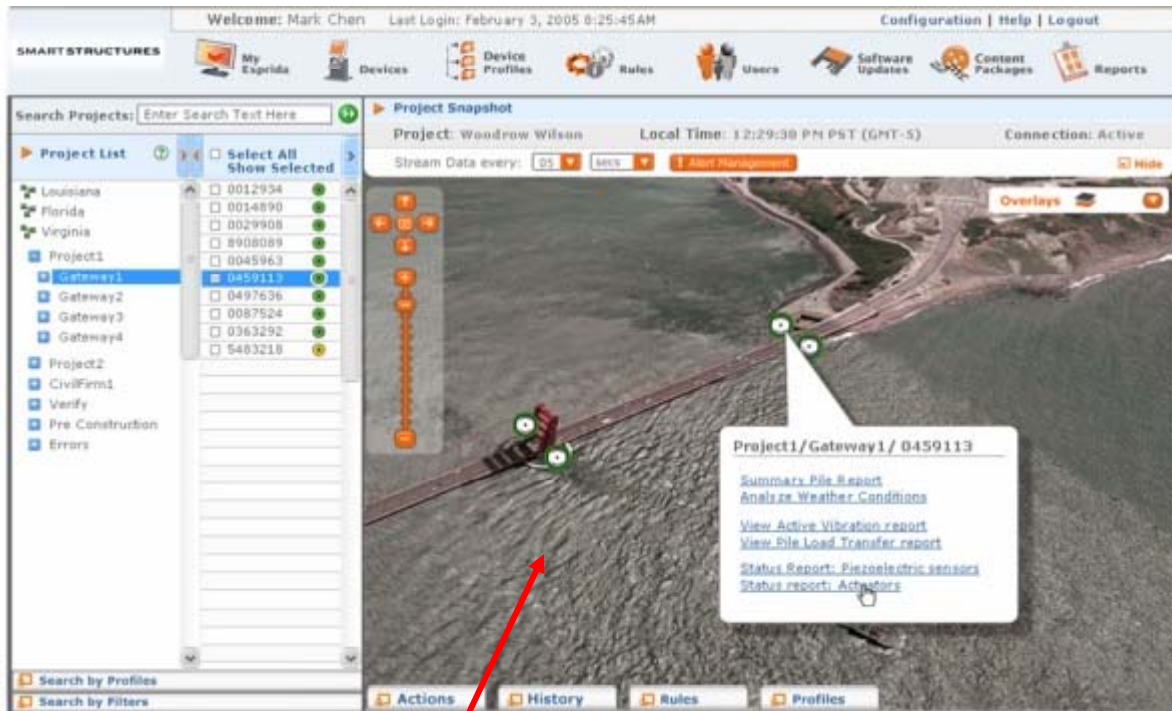
# Remote Monitoring - System User Interface

Geographic Information System

Alarms, alerting

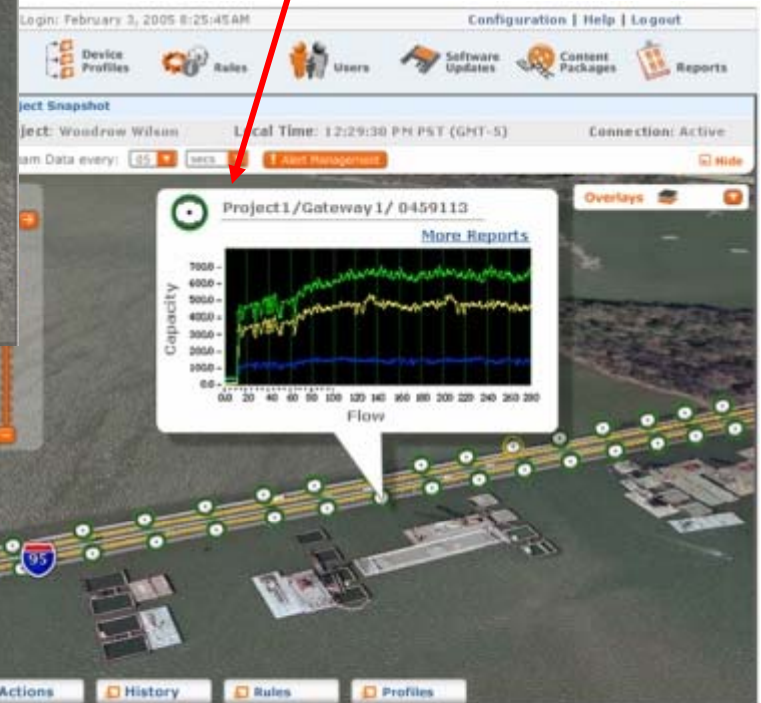
Condition-based maintenance

Situational Awareness



User can review sensor reading history by clicking on desired sensor position on structure

Actual sensor positions superimposed on satellite image



**Thank You**

