Improving Bridge Inspection, Scour Monitoring, and Infrastructure Management for DOTs using the Echoscope®

A true 3D, High Definition and Real-Time Imaging Tool

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Problem:

Preserving the Nation's infrastructure, roads and bridges is a top priority for Federal, State and Local Departments of Transportation (DOT). Balancing demand for new construction and maintaining current inventory in safe working condition is a challenge. With limited funding for bridge construction, bridges remain in service longer than their life expectancy and require maintenance to remain operational. Emphasis must be placed on frequent, cost effective and high quality bridge inspection processes to ensure these bridges remain safe. To meet this challenge, transportation leaders are investigating innovative technologies and methodologies to more efficiently conduct required periodic inspections at lower cost and with greater safety.

Currently, bridge inspections focus predominantly on the bridge superstructure and roadway surface. These inspections typically occur every 24 months. Underwater bridge foundations and substructures are typically inspected less frequently and are routinely only accessible with the use of qualified diving bridge engineers and inspectors. The frequency of substructure inspection varies by State and bridge scour classification; the maximum duration between inspections permitted by federal standards is 60 months. The Federal Highway Administration's (FHWA) underwater bridge inspection guidelines, currently define a three – tiered bridge inspection process to evaluate the bridge substructure and foundation through visual and non-destructive testing done by divers.

- Level I: Visual, tactile inspection
- Level II: Detailed inspection with partial cleaning
- Level III: Highly detailed inspection with Non-Destructive Testing (NDT) or Partial Destructive Testing (PDT)

Adapted from: FHWA-NHI-10-027, *Underwater Bridge Inspection,* 2010

Level I bridge inspections, conducted by certified bridge inspection divers, are the most common activity. A bridge inspector provides a detailed report including notes, photographs (if available), annotated maps of the bridge structure, and detailed recommendations for future repair, maintenance or further inspection. In general the reports for the substructure rely mainly on the diver's physical observations and ability to sketch the areas of concern. A "hand –over-hand" method is employed where a diver physically moves across the face and features of a structure to inspect for areas of concern, deficiencies and/or damage. It can be challenging to have an exact record of the bridge condition for future observation and analysis.

Sonars have been used to a small degree for remote depth monitoring, post navigational incident and search/recovery activities. However, bridge inspections are still primarily conducted using only divers. These inspections can be time consuming and present significant health and safety risks to divers. There are many conditions that can adversely affect a diver's ability to progress through the typical "hand-over-hand" method to inspect a bridge structure.

Some hazards and conditions that can impede diver inspections include:

- Strong currents
- Deep water depths
- Extreme cold temperatures
- Limited or no visibility due to fine suspended solids
- Confined spaces between structure and existing topography
- Unpredictability of floating and accumulated debris
- Watercraft and construction operations in proximity to structure and divers
- Ice floes
- Dangerous marine wildlife or protected habitats
- Time on station
- Bacteria, contaminants, or other materials hazardous to diver's health present in the water

Safety, operational time limitations on divers, and funding challenges have led Federal and State transportation agencies to evaluate acoustic imaging sonar systems as an alternative to provide detailed mapping and images to augment or replace dive operations. The ability to rapidly scan a bridge structure and identify potential damage, debris, or deficiencies is a must have for DOTs. Side-scan sonar systems have been employed over the past decade in trials and for post-incident analysis notably by the Florida and Virginia DOT with mixed results. The U.S. National Fish and Wildlife in Panama City, Florida currently uses side-scan imaging for habitat monitoring. However, a drawback to side-scan sonar usage noted by them is that "no two sonar images of the same area look exactly alike". Consequently, side-scan sonars are not ideal for infrastructure inspection, where repeatability, image resolution and comparing data on a regular basis are required.

A number of progressive DOTs collaborated to launch the Transportation Pooled Fund Study, TPF-5(131) Underwater Inspection of Bridge Substructures Using Underwater Imaging Technology in 2007. This current study's lead sponsor is the California Department of Transportation (Caltrans). Caltrans is responsible for one of the largest inventories of over water, long span bridges. Therefore better methods of inspection and maintenance are a large priority for its Office of Bridge Management and Specialty Investigations. The primary objectives laid out for the study were the following:

- Improve methods to assess the performance of existing transportation structures and increasing employee safety by reducing exposure of personnel to hazards encountered while performing underwater inspections.
- This proposal is to research the application of sonar imaging, remote operated vehicles and video technology as compared to diving inspections to satisfy the inspection requirements of the Code of Federal Regulations 23 CFR 650, Level I and II Underwater Inspections

The Study has compared various sonar types in different environments, deep and water shallow, high currents and varying visibility conditions. The Echoscope was a sound performer in swift currents and deep operations. The Final Report is set to be released in early 2015.

Solution:

The Coda Octopus Echoscope provides a real-time, geo-referenced, high resolution imaging that is intuitive and easily understood. It is uniquely suited to fill the role of a submerged structure imaging system that equals or exceeds the current standard of visual inspection. What differentiates the Echoscope's performance is the volume of data that is collected while scanning an underwater structure. Current side scan sonar systems only scan a structure with 128 beams per pulse; while the Echoscope's phased array generates an astounding 16,384 beams per pulse. As a result, inspectors visualize objects and features with more detail than previous sonar imaging systems would not have detected or visualized. Additionally, the Echoscope's Real-time processing allows inspectors acquiring the images to visualize data as it is being collected and decide if a second, closer look is needed. In the face of challenging budgets, the ability to react and maximize the time on a vessel is a valuable asset in completing structure scanning in a cost-effective and thorough manner. For example, 600 feet of structure can be surveyed with more detail than by a diver in less than 10 minutes.

The Echoscope is typically deployed on a small boat with a suitable attitude and positioning system with position, heading, pitch, roll and heave inputs. Fitting the sonar head to a pole mounted on the vessel's side is the most common method for inspecting bridges and structures at depths up to 175ft below the surface. But for deeper structures the Echoscope can be mounted on an ROV or AUV or alternatively, it can be mounted on a fixed tripod with an integrated Pan-and-Tilt head to execute a sector-scan method.

Figure 1: George F Young preparing to survey structures with the Echoscope

The Echoscope also provides users repeatability in scanning underwater infrastructure. Since the large volume of sonar return point-cloud data is geo-referenced, many of the repeatability and shadow problems associated with traditional sonars are relieved. The inspector can compare a recent structure scan image simultaneously with a previous scan.

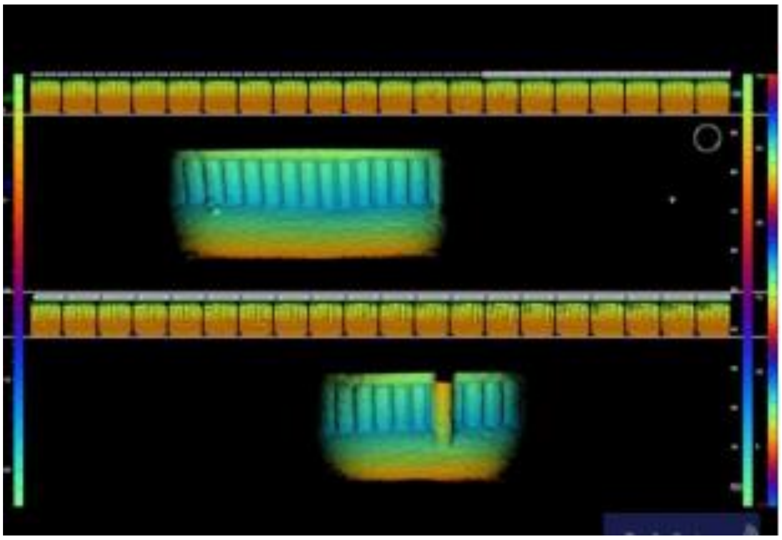

Figure 2: Comparing the current survey with a baseline survey enables ease in assessing changes over time

Bridge scour phenomena are indeed a significant concern for all DOTs. Bridge scour is the process by which sediment, debris, and structure components are weathered or transported by large flows and local velocities. Many existing bridge foundations were designed with minimal regard to scour; therefore the U.S. Army Corps of Engineers (USACE) and FHWA have mandated guidelines for scour assessment and program to target scour critical structures to regularly assess their condition. There have been three documented failures of bridges in the United States attributed to foundation scour since the 1970s. Prior to detailed record and investigation techniques, many bridges around the world have been lost due to large flow and flood events that washed out piers. The Echoscope brings a unique capability for inspectors - not only does it have the ability to provide high definition imaging of previous scour activities (holes, shoaling, debris, and exposed foundations) but it can be utilized to monitor in real-time the actions of tides, waves, high flow events or other actions that propagate scour and material migration. It can be used by inspectors not only to view scour but to evaluate scour trends over time. This Figure 1: George F Young preparing to survey structures with the Echoscope. Figure 2: Comparing the current survey with a baseline survey enables ease in assessing changes over time. 5 technology has been used in offshore wind projects to view scour and assist in power cable connections in Real Time.

Depicted are images of the Main Street /SR90 Bridge in downtown Jacksonville, FL. These scans were completed during a joint training workshop with the USACE – Jacksonville District and the Jacksonville Sheriff's Office (JSO). These images represent raw data that have not been post-processed or altered.

Figure 3: Main St. Bridge over the St. John's River in Jacksonville, Florida - Built in 1941

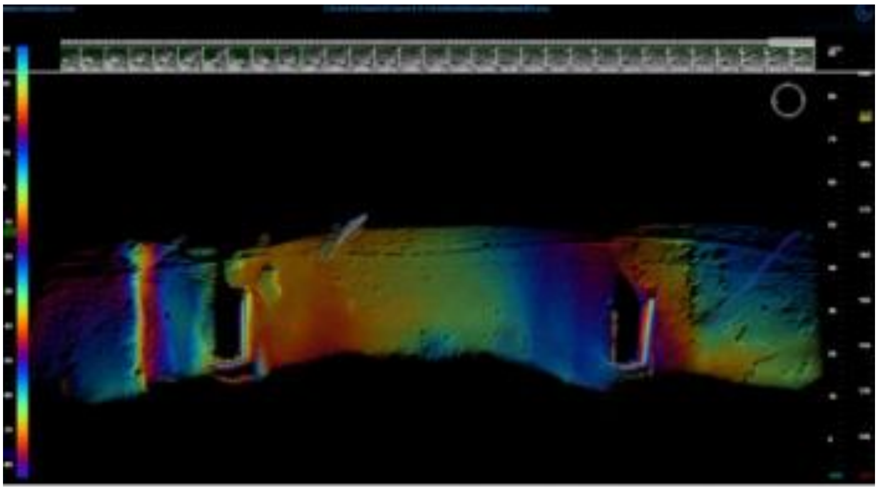

Figure 4: Inspection results of Main St. Bridge overall plan view mosaic (Note: only 1 pass on West side)

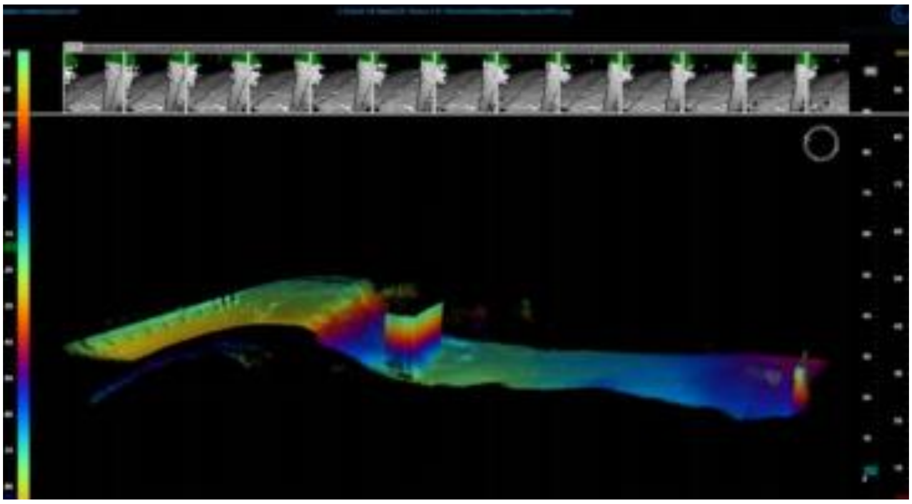

Figure 5: Main St. Bridge North Pier, seabed, utilities, and adjacent seawall

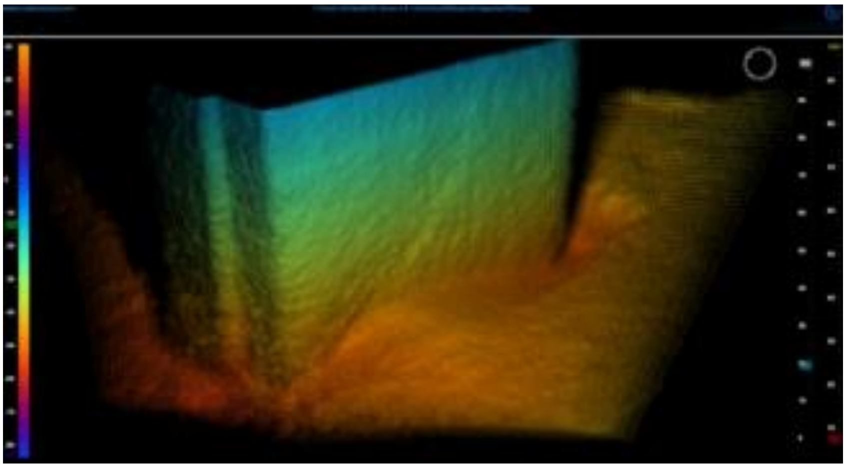

Figure 6: Main St. Bridge South Pier close up - depicting shoaling, visual marks

Many bridges, like normal surface streets act as homes for electrical, gas, high-speed data, and wet utilities. These utilities can be suspended beneath the superstructure or laying on the sea floor. The inspection and maintenance of submarine cables are critical to maintain service and avoid hazards to navigation. The Echoscope can be used for precise mapping of submarine cables and pipelines. With this technology project teams can strategically deploy divers, when needed, to physically inspect suspected damage or exposed areas, reducing costs and more quickly affecting repairs. Accurate and recent positioning of these conduits for future maintenance and construction of the bridge and channel navigation is now available.

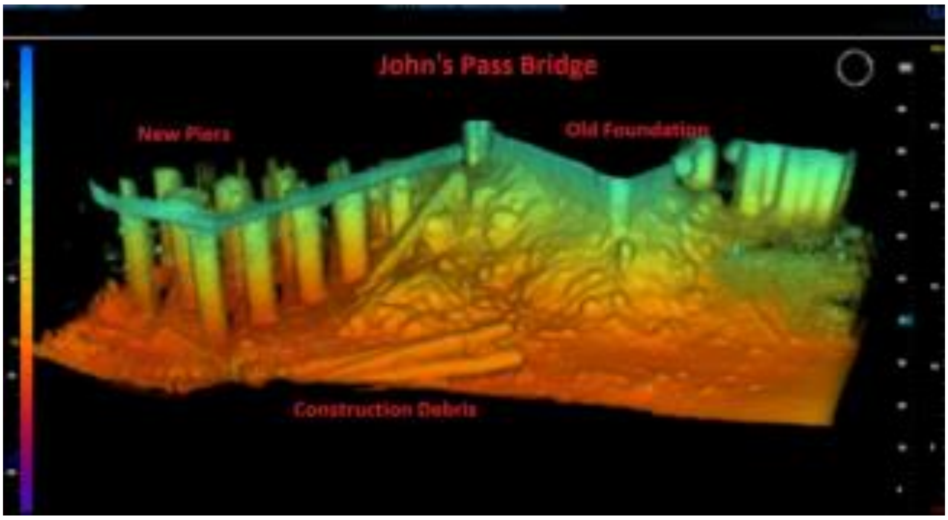

Figure 7: Survey showing broken pilings, shoaling and scour

Better methods for acquiring and recording data are now available to improve the quality and cost-effectiveness of these inspections. The Echoscope is a technology that has demonstrated that "Seeing is Believing" when it comes to developing high definition images, data, maps and videos of underwater structures. Implementing new technologies that can monitor in real-time large storm events, scour or other natural phenomena will lead to improved safety of our bridges today.

About the Author: Chris Gorman is a Registered Professional Engineer with broad civil project-based experience solving complex challenges with innovative technologies and construction methods. His project experience is focused in the U.S. Mid-Atlantic and Southeast regions. He currently resides in Central Florida.