March 2016

Final Report:

Smart Ports

Project Title: Smart Infrastructure

Competence Area: Hydraulic Infrastructure Engineering

Report type: Final Report

Author :

Patrick Hlabela

Jatin Harribhai

Mogau Seboqa

PREPARED BY:

CSIR

PO Box 395

PRETORIA

0001

DOCUMENT RETRIEVAL PAGE	
Report Number:	CSIR/BE/HIE
Report Title:	Smart Port
Authors:	P Hlabela, J Harribhai, M Seboqa
Date:	March 2016
Project Number:	B2GP100
Project Title:	Smart Infrastructure
Competence Area:	Hydraulic Infrastructure Engineering

Abstract:

South Africa is a developing country and has made its mark as one of the major maritime countries in Africa and the world. For it to compete internationally the ports of South Africa have to maintain an international standard it terms of safety and efficient operations within the ports. Transnet National Ports Authority (TNPA), who owns and manages the infrastructure of all eight commercial ports in South Africa have to ensure these standards are always kept.

This report is a literature review of the current and future technologies developed that can be adapted and implemented into the South African ports. The current technologies are used monitor the port infrastructure, vessels that navigating the port and vessels that are moored. However further refinement in these technologies is needed in South Africa.

The future if smart port technologies lies in the use of robotics both, in the air and on water to monitor the ports on a regular basis. This technology would allow for instantaneous access to data with no delays and collection of various data stored to a database for each port.

Keywords:	Ports, Smart Technologies, Robotics, Monitoring, Surveying

Table of Contents

1. PROJECT RATIONALE AND OBJECTIVE

South Africa has as a whole depends very heavily on our ports, as we are able to compete and trade on an international level with other maritime countries. In addition we are able to support the rest of Southern Africa in the movement of goods through the ports into the hinterland. Since we are part of the international trade, it is quite essential that our ports are of international standards in terms of operation and safety.

Transnet National Ports Authority (TNPA), who owns and manages the infrastructure of all eight commercial ports in South Africa; have invested a lot of money to ensure that commercial ports are upgraded to international standards. However maintenance plans for the older infrastructure have fallen by the wayside, as the ports can barely keep up with the new development. It was planned to use PG to develop and implement systems that are able to analyse the infrastructure in the port to be able to indicate weakness that need to be repaired. This would ensure investments into the port infrastructure are not wasted.

Currently the analyses of the port infrastructure especially the breakwater are done with the use of a helicopter and a survey boat. This technique has proven to be very unsafe for people on the helicopter and expensive. Another technique would need to be implemented to ensure that the safety factor is reduced and as well the expenditure is reduced, while ensuring efficient and accurate analyses is conducted.

A recent hot topic in the research community is the use of aerial drones (UAVs) to be able assist with analyses of breakwaters via aerial photos captured and; as well as the development of underwater robotics for ocean exploration. The use of robotics can be answer for safer and low cost, for breakwater monitoring and other port infrastructure.

2. PROJECT TASKS AND PROGRESS

The tasks undertaken for this project are as follows:

- Literature review of the current technologies available to monitor coastal structures.
- Literature of the possible future technologies that can be applied to monitor coastal structures.

This literature review is a compilation of the most recent as well as enhanced technologies that focus on the monitoring of port infrastructures particularly breakwaters, quay walls, port access channels as well as ship navigations.

The literature review seeks to find ways of reducing down time at ports by making sure that smart systems are put in place to monitor and alert ports in time if there are any problems that needs to be attended to.

Ports across the world have been looked into to find out what their current port infrastructure monitoring methods where and the most common results have been summarised in this report

To gain a background into this investigation a literature review is currently in progress. Several journal and articles on smart ports, aerial drones (UAVs), survey vehicles, underwater robots (AUVs) and swarm robotics are considered

With the data captured from the drones and the addition of the environmental data captured by the IPOSS system, a port would be able to accurately monitor the port infrastructure to predict downtime of a port

3. PROJECT DELIVERABLES or OUTCOMES

The current technologies are as follows:

- Breakwater Monitoring Technologies
- Quay Wall Monitoring Technologies
- Ship Navigation Monitoring Technologies

The future technologies are as follows:

- Aerial Drones (UAV)
- Autonomous Survey Vehicles (ASV)
- Swarm Robots (Integration of UAV with ASV)

3.1 Current Technologies

a) Breakwater Monitoring Technologies

Terrestrial Laser Scanning for Geometric Extraction and Change Monitoring of Rubble mound Breakwater at Baiona, Spain

Rubble mound breakwaters are coastal defence structures that protect harbours and beaches from the impacts of both littoral drift and storm waves. They occasionally break, leading to catastrophic damage to surrounding human populations and resulting in huge economic and environmental losses. Ensuring their stability is considered to be of vital importance and the major reason for setting up breakwater monitoring systems. Terrestrial laser scanning has been recognized as a monitoring technique of existing infrastructures. Its capability for measuring large amounts of accurate points in a short period of time is also well proven.

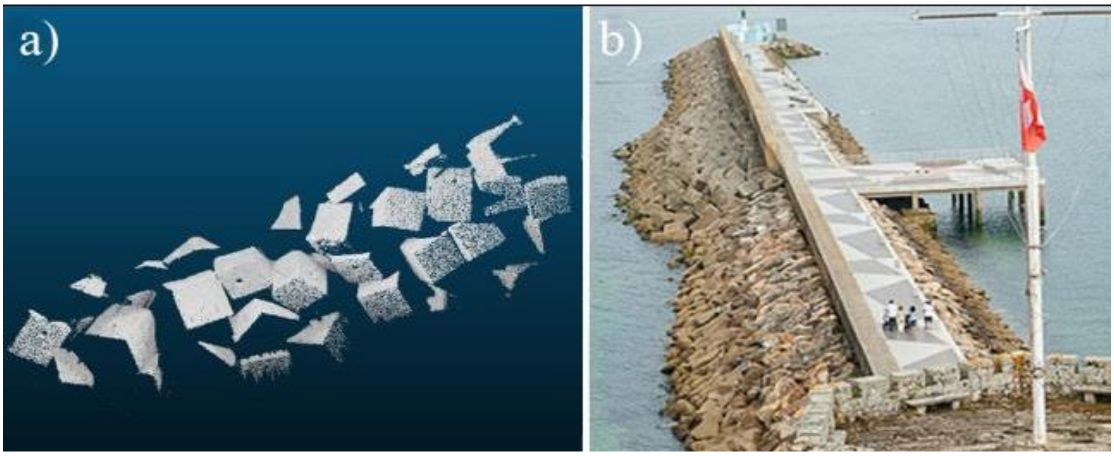


Figure 1: Baiona Breakwater

Field Implementation of Wireless Vibration Sensing System for Monitoring of Harbour Caisson Breakwaters

A wireless sensing system for structural health monitoring (SHM) of harbour caisson structures is presented. To achieve the objective, the following approaches were implemented. First, a wave-induced vibration sensing system was designed for global structural health monitoring. Second, global SHM methods which are suitable for damage monitoring of caisson structures were selected to alarm the occurrence of unwanted behaviours. Third, an SHM scheme was designed for the target structure by implementing the selected SHM methods. Operation logics of the SHM methods were programmed based on the concept of the wireless sensor network. Finally, the performance of the proposed system was globally evaluated for a field harbour caisson structure for which a series of tasks were experimentally performed by the wireless sensing system.

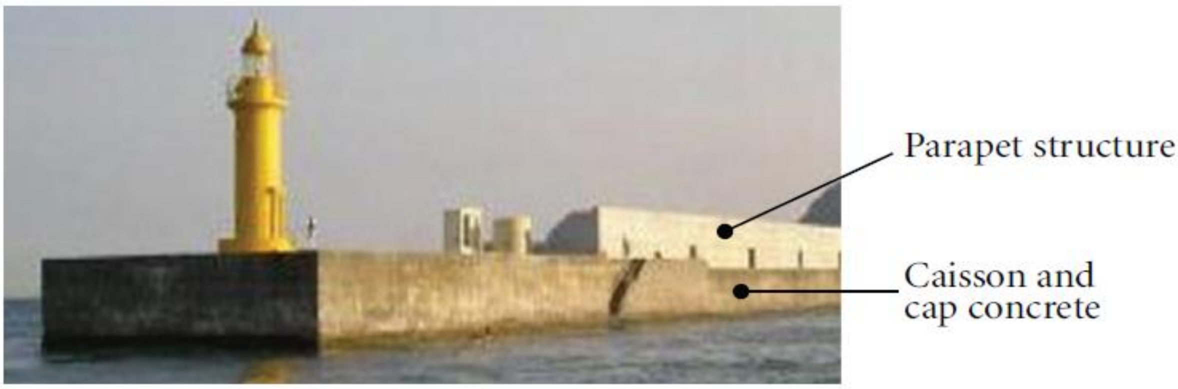


Figure 2: Oh-Ryuk-do cassion-type breakwater

Infrastructure inspections via LIDAR

Figure 3: Lidar data of breakwater

The Army Corps of Engineers manages over 1,000 coastal navigation structures, such as the Kaumalapau Harbor breakwater in Hawaii (pictured above).

General monitoring techniques include lidar or photogrammetric surveys, bathymetric sonar surveys, conventional ground surveys, walking inspections, and damage surveys that are more comprehensive than typical field inspections, according to the Corps' Costal and Hydraulics Laboratory. The data is compared to historical data and to standard design methods in order to improve designs.

b) Quay Wall Monitoring Technology

Measuring Ground Anchor Forces of a Quay Wall with Bragg Sensors

The use of optical fiber sensors for monitoring civil engineering structures is increasing continuously. One of the most frequently applied sensor types is the so-called Bragg sensor, which is primarily used to measure structural deformations. Due to some inherent advantages these sensors are ideally suited for long-term monitoring purposes. This paper describes the development of a load cell, based on Bragg sensors, to measure the forces in the ground anchors of a quay wall. After a short introduction on structural monitoring and the principles of a Bragg sensor, the concept of the load cell is discussed. Three ground anchors of a quay wall in Evergem, Belgium have been instrumented. After calibration in the laboratory, the load cells have been used to measure the pre stressing forces imposed on the anchors. The results show that the developed instrumentation is very well suited for this purpose. For more than one year, the anchor forces have been monitored at regular points in time. This indicates a dependence of the anchor forces on environmental temperature variations.

Monitoring of Harbour Structures in The Netherlands

Recent years have shown a significant development in the demand for monitoring harbour structures, and quay walls in particular, in The Netherlands. The purpose is to provide the particular structure with a comprehensive permanently installed system to monitor the overall structural behaviour including aspects such as soil erosion behind the retaining wall, strain and forces of the grout anchors, working loads on the quay structure as well as on the storage area behind it, deformation of the front of the quay wall, tilt of the superstructure, ground water level and harbour water level.

All sensors are permanently embedded and are designed and engineered to remain fully operational throughout the design life span of the structure itself. Because of their accuracy, reliability and durability fiber optic sensors are strongly recommended for demanding applications such as these. The reading units together with associated instrumentation are installed in a dedicated local central control room. From there the measurement data are transmitted automatically to a remote web server for processing and archiving. Authorised users of the port authority can log-in on this server. Data acquisition takes place at pre-set time intervals that may vary with the type and duty of the sensors. Alerts and alarms (usually 3 levels) are raised automatically via **email** and **SMS**.

The function of the monitoring system is threefold: to act as an early warning system for impending accidents, to provide long-term overall structural health monitoring and to enable the port authority to monitor the operations of the user.

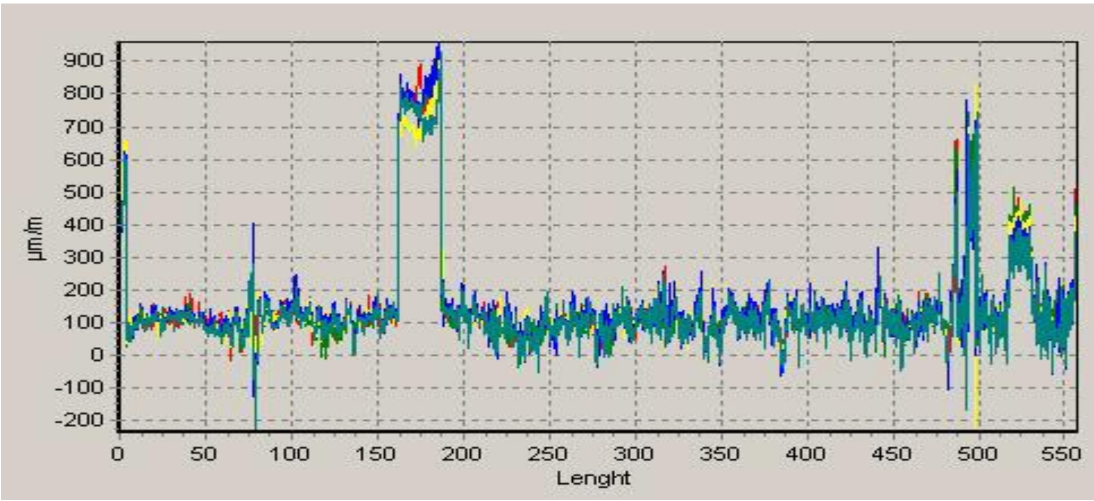


Figure 4: Distributed soil stability

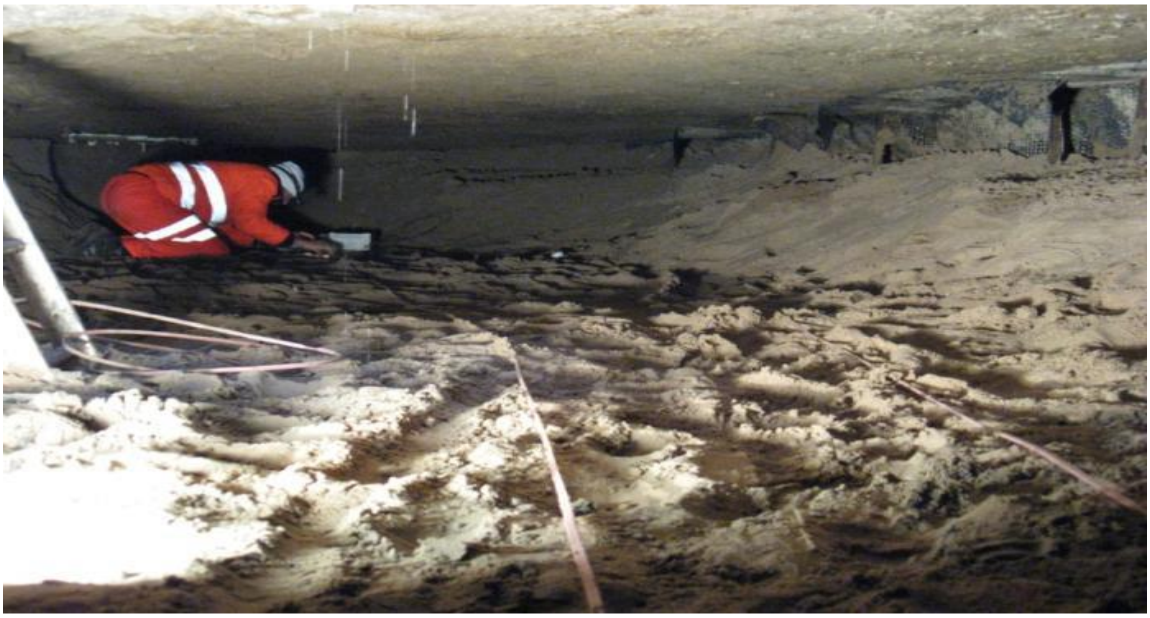


Figure 5: Soil erosion from underneath a Rotterdam quay wall

c) Ship Navigation Monitoring Technologies

Dynamic Underkeel Clearance (DUKC) is a world leading real-time aid to navigation that allows the shipping of more cargo, more safely, more often.

The DUKC Series 5 software consists of several modules integrated behind a web-based user interface. Each module is self-contained, developed and tested under ISO standards, and proven in the unforgiving world of maritime operations. The modules can be arranged and configured to help manage under keel clearance (UKC) related problems ranging from long-term voyage planning to real-time onboard pilotage applications and to the monitoring of numerous ships in real-time within a VTS environment.

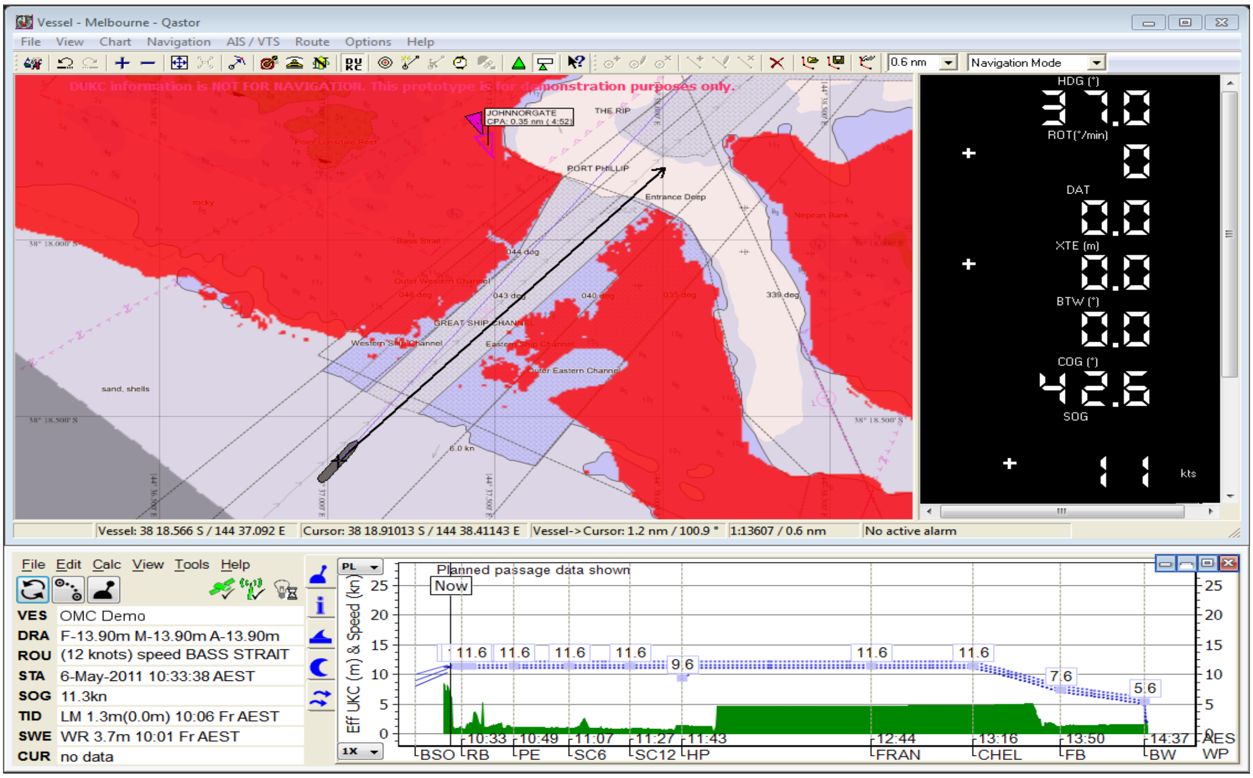


Figure 6: Chart overlay

Trelleborg Marine Systems designs

Trelleborg Marine Systems designs, manufactures and installs unique mooring hardware and monitoring software that is specifically configured and matched to your requirements.
Our solutions, which are built around the latest field-proven technologies, will be tailored to the needs of your project by our multi-disciplined team of engineers.

- Docking Aid Systems

Trelleborg SmartDock family of docking aid systems (DAS) monitor the approach and docking of vessels during berthing operations using lasers, differential GPS or Real Time Kinematic (RTK) GPS technologies. Various standard and customized designs are available to meet the widest range of berthing situations, including fender impact management.

- Environmental and MetOcean

According to your needs, they can supply standalone or integrated environmental monitoring systems for both marine and offshore applications.
Systems are designed to allow multi-user access to environmental and MetOcean data, which can be made available to portable devices on the vessel during approach and whilst moored at the berth.

- Integrated Control and Monitoring

Our specialised systems display vessel-to-jetty interface data through a single marine monitoring system to improve operations, management and control. As all key data is displayed in real time, operators are able to make more informed decisions. SmartHook load monitoring, remote release, SmartDock DAS and environmental modules are integrated into a single user interface at the Jetty Control Room and the data can be networked or sent over wireless communications to other locations as required.

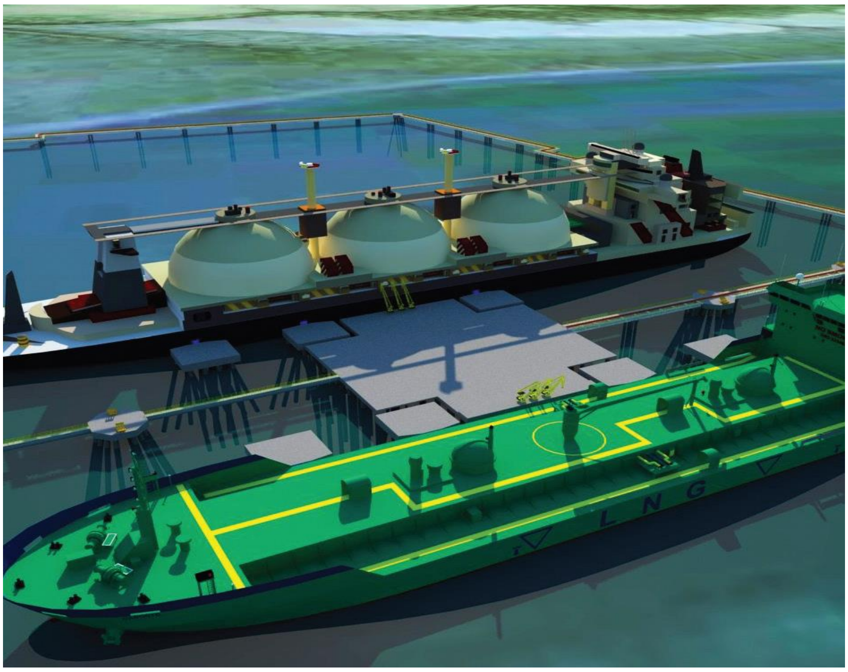


Figure 7: Docking Aid System

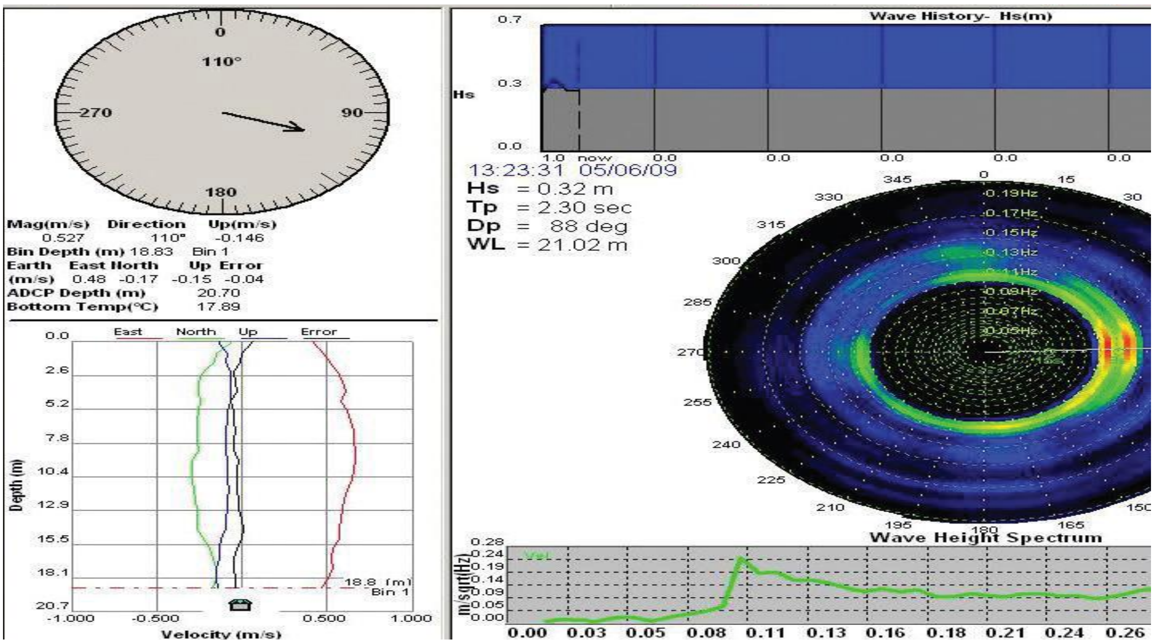


Figure 8: Environmental and MetOcean Monitoring System

3.2 Future Technologies

a) Arial Drones (UAV)

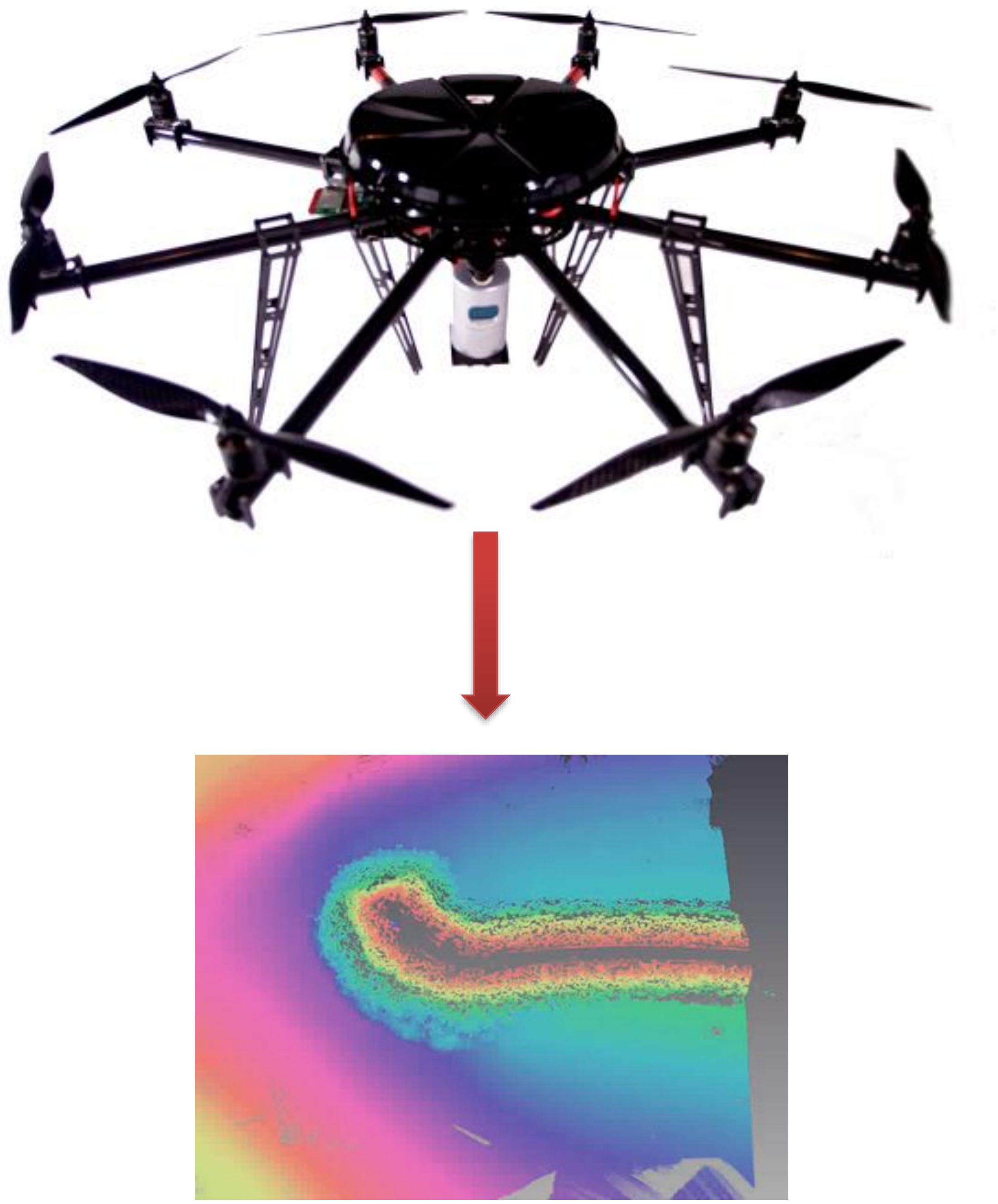


Figure 9: Aerial Lidar System

There many aerial drones on market but very few have been expanded to the coastal structures. With the use of aerial drones photographic and lidar surveys can be conducted of the breakwaters. Drones can be deployed at each port under the supervision of the port engineer to conduct these surveys anytime of the year and obtain instantaneous scans of the port. The benefits of using drones will reduce the delays in port and breakwater inspections, and reduce the human safety during the surveying process as no pilots are needed to do the surveys from the helicopters. Scans can be done on a monthly basis to build historical database of the port which would be beneficial to port engineers, coastal engineers and numerical modellers. Current drone systems navigate via waypoints set by the user, however a completely autonomous system can be developed using Simulatanous Localisation and Mapping Algorithm to make the robot navigate without waypoints. In autonomous navigation the drone will use GPS, Lidar and images to navigate on it owns.

b) Autonomous Survey Vehicles (ASV)

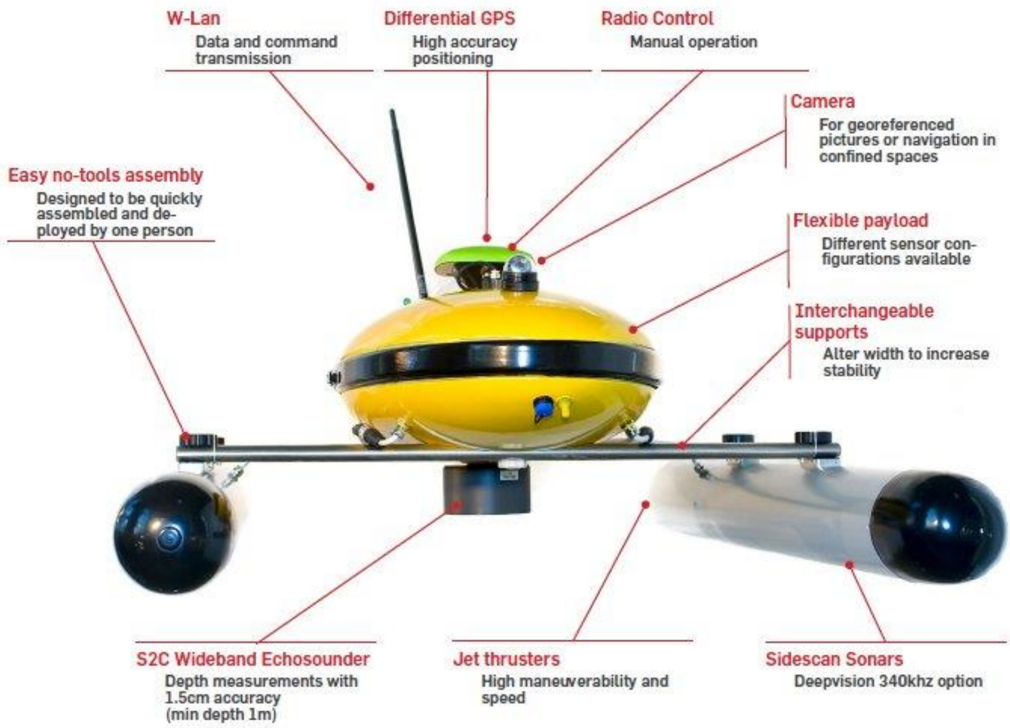
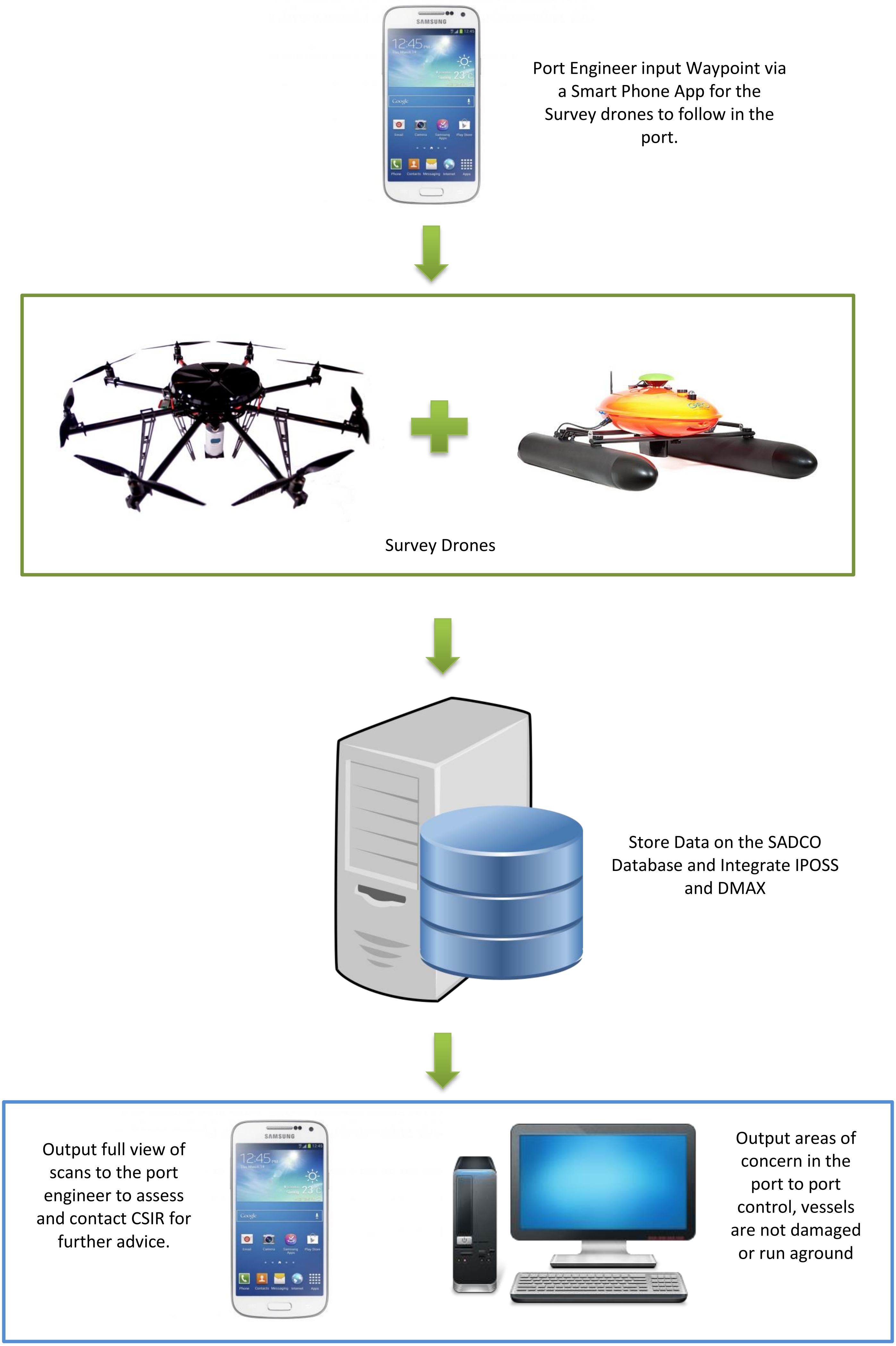


Figure 10: Semi- Autonomous Survey Vehicle (Sonobot)

Currently in all eight major ports in South Africa, bathymetry surveys are done twice a year. To ensure that regular dredging is conducted, more scans are required. Bathymetry surveys should be conducted on a monthly basis. Autonomous survey vehicles (ASV) can be deployed in each port to ensure that scans are done on a monthly basis and provide instantaneous results for port engineer. Specialized boat and crewman would not be needed hence this would reduce the cost and risk of the doing these scans more frequently. The current ASVs that have been used on port are the Sonobot by Evologics and Z-Boat by Teledyne Oceanscience. The ASVs navigate via waypoints and GPS set by the user.

c) Swarm Robotics (Integration of UAV and ASV)

In some cases both of the UAV and ASV would need to be used together to provide scans below and above water. One such case is when breakwater monitoring is conducted, as scans of the breakwater above water and below water is needed. A diagram of the integrations is shown on the next page.


Port Engineer input Waypoint via a Smart Phone App for the Survey drones to follow in the port.
Survey Drones
Store Data on the SADCO Database and Integrate IPOSS and DMAX
Output full view of scans to the port engineer to assess and contact CSIR for further advice.
Output areas of concern in the port to port control, vessels are not damaged or run aground

The previous page illustrated how the drones would operate and store data from the port. The integration of the ASV and AUV is known as swarm robotics. The port engineer can choose to operate them separately or let the one follow the other to endure data is fused correctly. The data collected would be send and store wirelessly the CSIR's SADCO database where both port engineers and authorized CSIR researchers have access to the data. During a deployment the results are sent to the port engineer and to port control. Port control would need the latest scans of the bathymetry to advise the pilots of the vessels entering the port of the safe and danger areas of the port.

4. CONCLUSIONS AND RECOMMENDATIONS

This report presents current and future technologies in monitoring and surveying port infrastructure. Much of the current technologies have been to be implemented in the ports South Africa but some are outdated and need upgrading.

CSIR together with TNPA are using the latest LIDAR and multi-beam sonar scanners to survey and monitor the quay walls and breakwaters in the ports. Research is also being conducted to incorporate survey drones, as presented in this report, the current technologies. CSIR is currently investigating to develop survey drones or modify current drones to be able to gather data for the SADCO database. Currently this investigation is purely a literature study reviewing the latest drone technology available. Further funding is needed to buy or build the drones required for the surveys.

TNPA have just installed new software to monitor the safe navigation of the vessels in the port. However CSIR would need to analyse the data for TNPA to ensure the software is validated to provide statistics for port planning and management. Monitoring of vessels that are moored is not currently implemented in all the ports. To ensure the safety of vessel, port operators and infrastructure some monitoring system is needed. TNPA could use the technologies that presented in this report or CSIR can develop a monitoring system for them.

References

1. ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume II-5, 2014
2. ISPRS Technical Commission V Symposium, 23 – 25 June 2014, Riva del Garda, Italy
3. International Journal of Distributed Sensor Networks Volume 2012 (2012), Article ID 597546, 9 pages
4. Hindawi Publishing Corporation International Journal of Distributed Sensor Networks, Volume 2012, Article ID 597546, 9 pages doi:10.1155/2012/597546
5. Journal of Structural Engineering, Volume 131, Issue 2 (February 2005)
6. EACS 2012 – 5th European Conference on Structural Control Genoa, Italy – 18-20 June 2012, Paper No. 251
7. Patrick Marshall, LIDAR mapping projects explore the fourth dimension, March 14, 2013
8. Trelleborg Marine Systems, Docking and Mooring.
9. Teledyne Oceanscience, Z-Boat
10. Evo-logics, Sonoboat
11. Suasnews, XactMaps Debuts World's First GPS-Free UAV Aerial LIDAR Surveying And Mapping System