Design of a Prototype Tsunami Warning and Early Response system for Cyprus - TWERC

George Georgiou[1], Andrew M Clark[2], George Zodiatis[1], Dan Hayes[1], Dimitris Glekas[3]
1. Cyprus Oceanography Centre, University of Cyprus, Nicosia, CYPRUS
2. CSnet International, Inc, Stuart, Florida, USA
3. CSnet (CYPRUS) Ltd., Limassol, CYPRUS

Abstract – **Described is the expansion of an existing and operational ocean observatory known as CYCOFOS (Cyprus Coastal Ocean Forecasting and Observing System), with a network of tsunami detection sensors. The expanded network will serve as the prototype Tsunami Warning and Early Response system of Cyprus (TWERC). The potential in Cyprus for extensive onshore destruction from a seismically generated tsunami is significant. Currently, the state of the art in tsunami detection is achieved with bottom pressure recorders (BPRs). One alternate approach utilizes GPS to measure vertical displacements of a buoy moored near shore in conjunction with fixed differential beacons on shore. More recently, algorithms have been developed that enable a GPS-equipped buoy to accurately detect a tsunami without the need of a nearby shore-based differential reference beacon, thereby extending the range of its moored distance to perhaps hundreds of kilometers from shore, providing more time to issue a warning. The existing CYCOFOS buoy provides a unique platform to evaluate this technique since it is capable of supporting both the conventional BPRs on the seafloor while simultaneously operating the GPS suite at the surface. The GPS-only method portends to improve the ability of coastal nations to protect their citizens from devastating tsunami through both reduction in complexity and cost compared with current techniques. This is particularly vital to the populations of developing countries. Detecting a tsunami is of practical use only if that information can be conveyed rapidly to the coastal inhabitants, and they know immediately what to do. Therefore, the TWERC project will also develop the framework for the capacity building required to alert the coastal population as well as develop and test a preliminary plan for educating both the resident and visitor population of Cyprus and the government decision makers who must implement the plan. The TWERC is aligned with the North East Atlantic and Mediterranean Tsunami Warning System (NEAMTWS).**

I. Introduction

. A program has been launched to expand the existing CYCOFOS (Cyprus Coastal Ocean Forecasting and Observing System) observatory operating off the south coast of Cyprus with a network of tsunami detection sensors that will serve as the prototype Tsunami Warning and Early Response system of Cyprus (TWERC). The potential in Cyprus for extensive onshore destruction from a seismically generated tsunami is significant, shown by historical records and recent statistical studies [1]. The tsunami threat is exacerbated by the relatively narrow width of the Mediterranean Sea, providing perhaps only minutes of warning (compared to hours in larger ocean basins) [2]. The high density of coastal population and infrastructure make a robust, real time tsunami detection and warning system particularly vital. Currently, in other parts of the world, tsunami detection is achieved with expensive bottom pressure recorders (BPRs) that are difficult and costly to maintain and rely upon costly and problematic acoustic telemetry modems to carry their signal from great depths. Another technique being implemented in Japan, utilizes GPS to measure vertical displacements of a buoy moored near shore in conjunction with fixed differential beacons on shore [3]. More recently, algorithms have been developed that may enable a GPS-equipped buoy to accurately detect a tsunami without the need of a nearby shore-based differential reference beacon, thereby enabling it to be stationed perhaps even hundreds of kilometers from shore, providing more time to issue a warning [4], [5], [6]. The existing CYCOFOS buoy provides a unique platform to evaluate this potentially revolutionary technique since it is capable of supporting both the conventional BPRs on the seafloor while simultaneously operating the GPS suite at the surface. Thus, an immediate, proven tsunami detection network for Cyprus is assured while also developing this new technique. The GPS-only method portends to radically improve the ability of coastal nations to protect their citizens from devastating tsunami with drastic reduction in complexity and cost compared with current techniques. This is particularly vital to the populations of developing countries where the majority of tsunami occur. Detecting a tsunami is of practical use only if that information can be conveyed rapidly to the coastal inhabitants, and they know immediately what to do. Therefore, this project will also develop the framework for capacity building required to alert the coastal population as well as develop and test a preliminary plan for educating both the resident and visitor population of Cyprus as well as the government decision makers who must implement the plan. This project will result in a functioning pilot scale demonstration of a civil defense system operated through partnering of the public and private sectors. At the same time, it will make a significant contribution to the current

978-1-4244-5222-4/10/$26.00 ©2010 IEEE

knowledge base and state of technology that can benefit literally millions of others around the globe, particularly in some of the most disadvantaged regions of the world. The goals of this project are aligned with those of the North East Atlantic and Mediterranean Tsunami Warning System (NEAMTWS), to which TWERC will be adopted through the Cyprus Oceanography Centre, a member of the NEAMTWS.

II. OBJECTIVES

The offshore component of the existing CYCOFOS infrastructure consists of a surface buoy moored to instruments on the seafloor by way of a cable containing both power conductors and optical fibers for data transmission. The CYCOFOS surface buoy is a variant of the Ocean Net(TM) system designed and manufactured by Maritime Communication Systems (MCS).

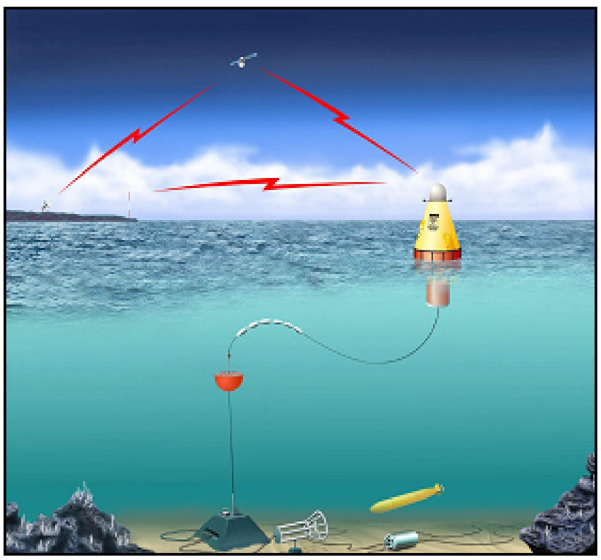

Figure 1. Existing CYCOFOS Observatory

Atop the surface buoy is an inertially stabilized C-Band satellite antenna capable of remaining locked-on to a geosynchronous communications satellite through sea state 6 conditions. The data bandwidth throughput provided by this link is in excess of 2 Mbps. The buoy is powered by a diesel electrical generators that sends over 1 KW of power to the seafloor. Presently installed on the seafloor is an anchor for the buoy and approximately 2 km of data/power cables connecting the buoy to a single Junction Box. The Junction Box is equipped with multiple wet-mateable "plug-in" ports enabling scientific and environmental sensors to be added. The power and bandwidth available is currently underutilized. What's more, as presently configured, the seafloor portion of the CYCOFOS system consists of only the single Junction Box (or node) and so allows for data to be collected only at one location on the seafloor. The CYCOFOS buoy is capable of transmitting much more power to the seafloor and far more data to shore, but it is limited by the area of ocean it can monitor and the number of instruments that can be plugged into it. In addition to adding a suite of GPS sensors to the surface buoy for evaluation of the long-base line RTK-GPS surface elevation measurement, the spatial footprint of the extent of the seafloor component of CYCOFOS is being significantly expanded for the new TWERC as shown in Figure 2.

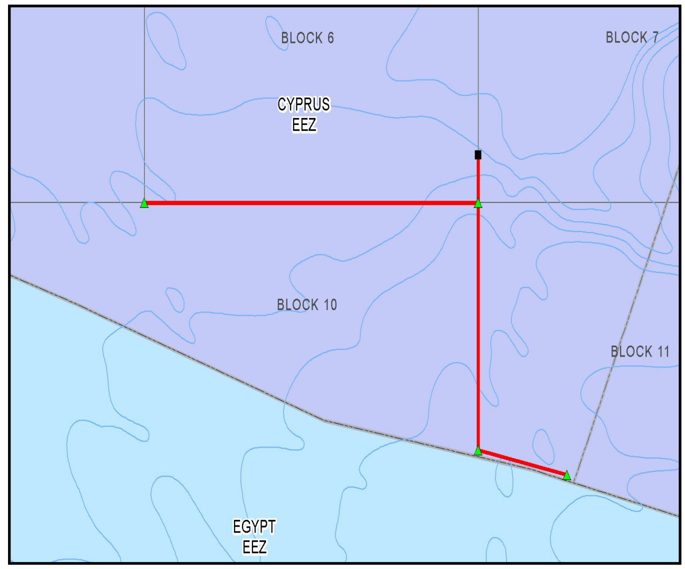

Figure 2. TWERC seafloor array configuration

In order to be able to resolve the direction of both any incoming seismic (ground) and surface (water) wave, an orthogonal "L" shaped array of seafloor Junction Boxes or "nodes" is being deployed incorporating both Bottom Pressure Recorders (BPRs) and Ocean Bottom Seismometers (OBSs) at each node. The nodes are spaced far enough apart from each other in order to enable triangulation of the data obtained from the OBS and BPR to determine the direction of the source. The fourth node, the eastern-most node depicted in Figure 2, serves as a point for further expansion of the network. In addition to supporting the TWERC, this Offshore Communications Backbone (OCB) is also intended to support other research and environmental monitoring. As depicted in Figure 3, this fourth node is situated at the base of a seafloor feature of extreme interest [7], the Eratosthenes Seamount. With its base at a depth of over 2,500 meters and towering to within 700 meters of the sea surface, this unique structure is a likely target for possible future expansion of the network. Future plans include adding other instrumentation to the network, include among them low light level and high resolution video and still cameras, lighting, and sensors for chemical and biological monitoring.

Without real time continuous reporting capabilities, the other BPR-based tsunami detection systems currently deployed around the world [8], [9] are not capable of detecting and reporting non-seismically generated phenomena (e.g. “rogue waves”) nor are they useful in providing oceanographic now-casting data. The widely spaced, continuously operating and monitored BPRs of the TWERC will make it possible to calculate the depth-averaged geostrophic transport perpendicular to the axis formed by any two nodes in near real time, which can then be compared with ocean forecasts produced daily by CYCOFOS for the purposes of model validation and model development. This added capability represents another new research tool available to the scientific community that will be in operation for many years.

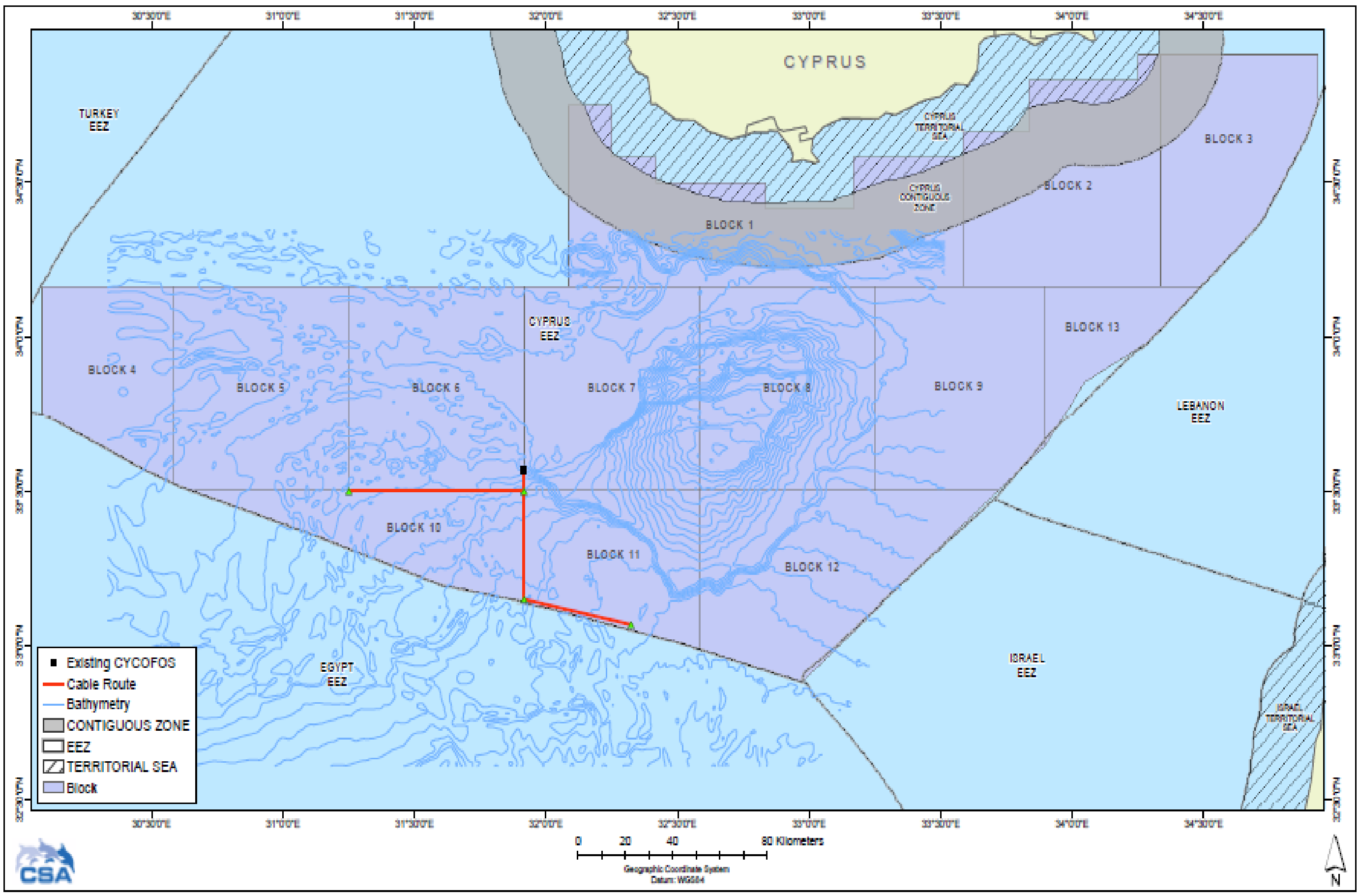

Figure 3. Expanded TWERC array in proximity to Eratosthenes Seamount

III. COMPONENTS

Figure 4 depicts the three seafloor nodes comprising the "L shaped" array being readied for deployment. The nodes were manufactured by Ocean Works based upon specifications provided by Maritime Communication Services (MCS). Among the unique capabilities incorporated into the design of these TWERC nodes is their "skip node" feature [10]. Redundant switching and a built in bypass path incorporated into in each node allows power and signal to continue unimpeded past any adjacent node in the network that may have failed.

Figure 4. Seafloor nodes being readied for deployment

Each of the nodes is fitted with three TE SubCom "Milennia" couplings. These connectors both facilitate tying into the OCB backbone as well as branching for further expansion of the network. Figure 5 depicts these couplings as they are installed on the seafloor nodes.

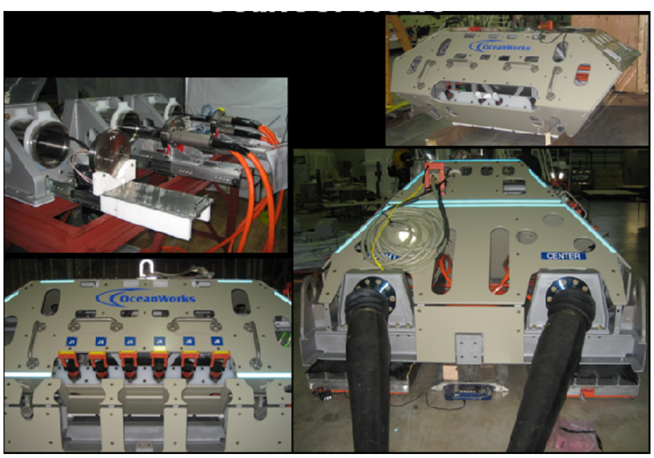

Figure 5. Milennia Couplings on seafloor nodes

IV. CAPACITY BUILDING

Finally, a tsunami warning system cannot be effective unless those who receive the warning know what to do with the information. This local awareness and understanding can only come from community partnerships and proactive education and outreach efforts before the warnings are issued. Effective education and outreach can best be achieved by fostering partnerships among community organisations and local agencies that can help educate the public about the warning system and how to respond. Public education is a critical component of disaster preparedness. A recent series of international meetings on establishing a tsunami early warning system for the Indian Ocean focused initially on the technical aspects [11] -- moored buoys, tide gauges and satellite communications that link them to monitoring centers. However, the Director of the U.N. International Strategy for Disaster Reduction Secretariat, addressed the need for public outreach and education in creating an early warning system stating, "If the warnings do not get to the people at risk and into public education and preparedness programs, they will be ineffective." According to the Ministerial Declaration on Regional Cooperation on Tsunami Early Warning Arrangements at the meeting of participating governments convened in Phuket, Thailand after the devastating tsunami of 26 December 2004, in order to be effective, a tsunami warning system requires a number of elements: risk assessment, hazard monitoring and detection, prediction and formulation of warning, dissemination and communication of warning messages, and knowledge and preparedness to act. In order to promote tsunami hazard preparedness in Cyprus, a collaboration among local emergency managers, the general public and local businesses such as coastal resort hotels is necessary. Such collaboration will support greater and more consistent tsunami awareness and mitigation efforts among the communities at risk.

In the United States, the National Oceanic and Atmospheric Administration (NOAA) has developed a program called "TsunamiReady" [12] to educate local emergency management officials and their constituents and promote a well-designed tsunami emergency response plan for each community. A voluntary program based in part on the TsunamiReady concept will be carried out in Cyprus. Based upon surveys and outreach activities with coastal communities in Cyprus, a grassroots approach to develop plans to handle wave impacts and flooding threats, and inform citizens of threats associated is currently being planned.

Figure 6. Sign alerting public to tsunami evacuation in Vina del Mar, Chile 2010

V. The Path Forward

Thus far to date, extensive bathymetric surveys have been conducted to accurately define the complex seafloor features of the area (Figure 7). This is important both to characterize unique features such as the seamount and also to determine the best routing for interconnecting cables between the seafloor nodes. The current plan is to deploy the TWERC in late 2010 to early 2011.

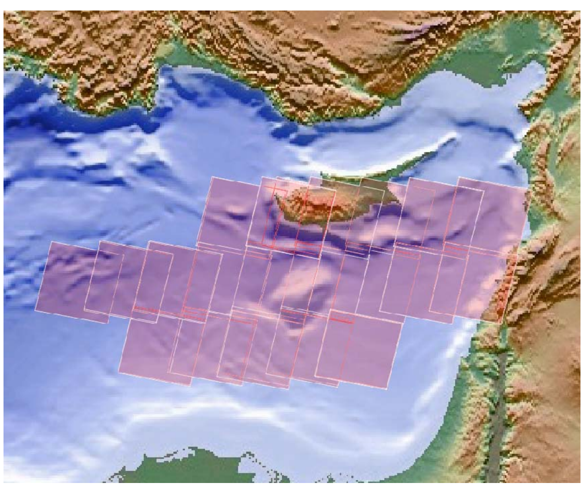

Figure 7. Bathymetry including southern EEZ of Cyprus

Acknowledgment

The authors wish to thank the National Hydrographic Survey Committee of Cyprus, the Cyprus Ministry of Foreign Affairs and the Energy Directorate of the Ministry of Industry, Commerce and Toursim for their support of the TWERC effort. Additional acknowledgment to Drs. Erricos Pavlis and Oscar Colombo of the University of Maryland Baltimore County for their seminal work and contributions in the fields of satellite altimetry calibration-validation and GPS-based tsunami detection, the results of which are vital to the success of this program.

References

[1] Fokaefs, A. And G.A. Papadopoulos, 2007, "Tsunami hazard in the Eastern Mediterranean: strong earthquakes and tsunamis in Cyprus and the Levantine Sea", *Nat Hazards, 40, 503-536.*

[2] Hanka, W., J. Saul, B. Weber, J. Becker and GITEWS Team, 2008, "Timely Regional Tsunami Warning and Rapid Global Earthquake Monitoring", *ORFEUS Newsletter, 8(1).*

[3] Clark, A.M and E. Pavlis, 2008, Adapting Existing Systems for Tsunami Detection, Proc. Of IEEE Chile-US Workshop on Ocean Observation Systems, Vin del Mar, Chile.

[4] Colombo, O, M. Pajares, M. Juan and J. Sanz, 2005, Extending Wide Area and Virtual Reference Station Networks Far into the Sea with GPS Buoys. Proc of the Inst of Navigation, ION-GNSS, Long Beach, CA.

[5] Colombo, O, A. Sutter and A. Evans, 2003, Evaluation of Real-Time, Long Range, Precise, Differential, Kinematic GPS Using Broadcast Orbits. Proc of the Inst of Navigation, ION-GNSS, Portland, OR.

[6] Earth and Climate, e!Science Newsletter, 10 Nov 2008, A new approach in tsunami early warning. http://esciencenews.com.

[7] Zodiatis, G., Lardner L., Demirov E., Georgiou G., Manzella G. and Pinardi N., (2003). An Operational European Global Ocean Observing System for the Eastern Mediterranean Levantine Basin: The Cyprus Coastal Ocean Forecasting and Observing System, *J. of Marine Technology Society*, v.37,no.3, 115-123.

[8] Gonzalez, F. et al., 1998, Deep Ocean Assessment and Reporting of Tsunamis (DART). Proc of International Workshop on Tsunami Disaster Mitigation, 19-22 January.

[9] Green, D, 2006, Transitioning NOAA Moored Buoy Systems from Research to Operations. Proc of the MTS/IEEE Oceans '06 Conference, Sept Boston, MA.

[10] Clark, A.M et al., "Numerical Modeling and Hardware-in-the-Loop Simulation in the Design of Undersea Networks, Ocean Observatories and Offshore Communication Backbones", *Proc of MTS/IEEE Oceans09 Conference*

[11] US Dept of State, International Information Programs, IWS, March 2005. http://www.iwar.org.uk.

[12] US National Weather Service, NOAA, TsunamiReady website, http://www.tsunamiready.noaa.gov.