# Low-Cost Efficient Wireless Intelligent Sensor (LEWIS) Deployment for Community Driven Decision Making

SANDEEP ALAMPALLI, KAVEH MALEK,
ALI MOHAMMADKHORASANI and FERNANDO MOREU

**ABSTRACT**

There have been several advances in Structural Health Monitoring (SHM) throughout the last two decades. Among these advances is that sensors and data acquisition have become smaller in size while wireless technologies have been making wireless communication and data accessing easier. These advances create cost effective sensing solutions for communities where flooding and wildfires put their members and infrastructure at risk. Therefore, with higher community involvement in understanding and utilizing new sensing technologies, there is more to be gained in preparing for and mitigating the effects of natural hazards. Low-cost easily deployable sensors will make sensor technology more popular and easier for communities to utilize and give them the ability to make decisions during natural hazards. LEWIS, a Low-cost Efficient Wireless Intelligent Sensor platform, is created by the Smart Management of Infrastructure Laboratory (SMILab) at the University of New Mexico (UNM) at Albuquerque for such a purpose: to give communities the ability to create innovative monitoring solutions, including combating climate change. This paper briefly discusses the LEWIS platform, their use for communities to combat natural hazards to make quick decisions to improve public safety, training and education components, and community (from student to industry professional) engagement efforts.

**BACKGROUND**

Structural health monitoring (SHM) refers to the monitoring of structures to assess their performance on a continuous basis for decision making [1]. Data collected depends on the application at hand. Due to innovations in the last two decades, SHM has become more cost-effective to implement [2]. The use of these systems can only be utilized frequently if communities can build and deploy these sensors with off-the-shelf components. This requires the sensors to be built at low-cost as well as to expose and

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Sandeep Alampalli, Stantec, 475 5th Ave 12th Fl, New York, NY 10017, U.S.A.
Kaveh Malek, Ali Mohammadkhorasani, and Fernando Moreu Spangler, University of New Mexico, Albuquerque, NM, 87131, U.S.A.

train communities on sensors and systems. The SMILab team has been working to make SHM more useful for communities in New Mexico State and to advance this concept [3].

A primary application of the LEWIS 5 platform [4] and its networks is to deploy them in areas that are at risk for natural disasters such as heavy flooding and wildfires. Rainfall accumulation, infiltration and water runoff in urbanized areas are essential in understanding the impacts of flooding on infrastructure. The impact flooding has on infrastructure varies from minor repair to transportation shutdowns and the potential collapse of infrastructure. Areas within New Mexico are regions that suffer from risks and damages due to flooding. A wireless network of LEWIS would be able to monitor real-time flooding events and record data for creating an approach to combating flood risks and damages. LEWIS sonar, rainfall, and camera sensors are configurations of standard Wireless Smart Sensors. LEWIS are portable, versatile, minimal cost, and simple to deploy. These sensors are interconnected wirelessly using a hotspot to create a LEWIS network upon deployment. A LEWIS unit can be modified and set-up in the field and has been developed for a wide variety of tasks including water elevation and vibration monitoring.

LEWIS network deployments rely on partnerships between communities and the SMILab team ensuring that useful data is collected to create meaningful solutions for these communities. The impact of this research is focused on community based SHM, i.e., in exploring how the teaching and introduction of low-cost sensors can benefit the adoption by the community to new sensing technologies, which can be of value for the future direction and growth of SHM as a tool for the community. Researchers propose to ask first the owner on which type of sensor they are interested to use and enabling the community to change the sensor, the data analysis, and the implementation.

## INTRODUCTION TO LEWIS

LEWIS was first conceptualized with the constraints being that the sensors must be rapidly deployable and reliable in the field while being fabricated at low-cost, wirelessly interconnected, self-sustaining, and data accessible via the internet. In order to accommodate diversified SHM applications, LEWIS has many different variations as well, with every variation requiring different sensor modules while retaining the same core components.

The LEWIS 5 camera (Figure 1) can capture video feed from the site of deployment and save the feed to an SD card or make the feed accessible via website. The core components of the LEWIS 5 camera are the same as the LEWIS 5 sonar and rainfalls variations with the only difference being the sensing module (ESP 32 Camera) and the method of deploying the sensors at the site.

Figure 1. LEWIS 5 camera

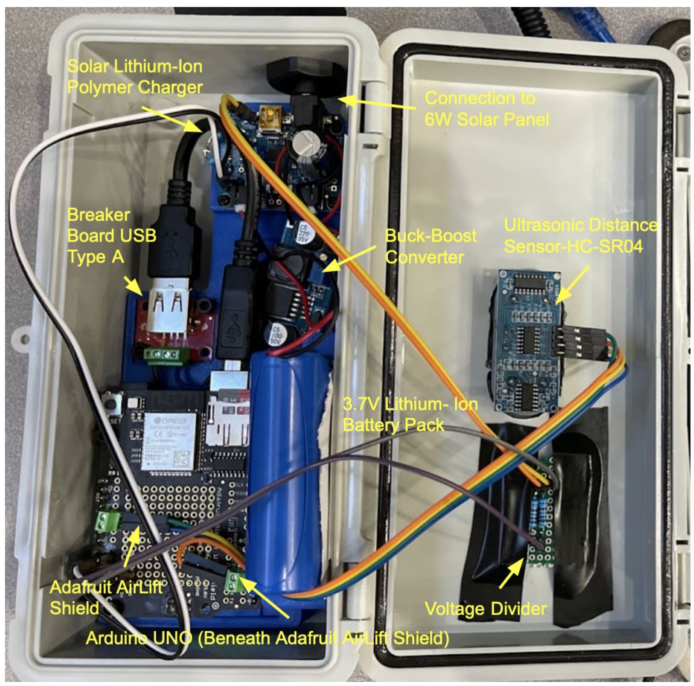


Figure 2. LEWIS 5 sonar variation

The LEWIS 5 sonar (Figure 2) is one of the more widely used LEWIS platform units with its capability to consistently measure the distance between the point of deployment and the ground beneath it. The sensor can effectively monitor changes in water level and ponding/stream depth over a period of time. The LEWIS 5 sonar utilizes an off-the-shelf ultrasonic sensor almost identical to the widely used HC-SR04 ultrasonic sensor. The ultrasonic sensor is accurate to within 3mm. The microcontroller (Adafruit Airlift Shield and Arduino UNO) and power circuitry are identical throughout all LEWIS 5 units with the main differences being wiring and sensor components such as the ultrasonic sensor in the LEWIS 5 sonar. Every LEWIS 5 unit is powered using a 5V 5W solar panel and a rechargeable lithium-ion battery as shown in figure 2. When deployed in the field, the solar panel recharges the lithium-ion battery pack and powers the sensor throughout the day. During the night, the battery pack will power the sensor.

Irrespective of the variations in LEWIS units, the sensors can exist within the same network and offer the user multiple forms of real-time remotely accessible data. Many initial LEWIS 5 deployments featured the LEWIS 5 units on top of tripods as shown in figure 3. In these initial deployments, the LEWIS 5 sonar and rainfall units were deployed as not only a proof of concept (Figure 3), but also as to test the consistency of data acquisition, lifetime of the sensor as well as the hotspot, and data visualization. The LEWIS 5 rainfall detects rainfall events and rate of rainfall. Like all LEWIS 5 units, the data is visible in real-time via a website that logs every active and inactive LEWIS 5 unit. LEWIS 5 units in the field are able to connect to the internet via mobile solar-powered hotspots in the field alongside the sensors.

Figure 3. Deployed LEWIS 5 Sonar and LEWIS 5 rainfall attached to a tripod.

Figure 4. STEM Expo in Albuquerque, New Mexico

Figure 5. SMILab team presenting LEWIS and their applications to industry.

## COMMUNITY OUTREACH

The utility LEWIS offers communities is reliant not only on a reliable sensor network, but also a strong partnership between SMILab and the communities SMILab works with to develop infrastructure and natural hazard solutions. At the root of the partnership lies an education component where SMILab hopes to positively impact students, industry professionals, and the general public by teaching and exposing them to the LEWIS project (see Figure 4).

Demonstrating the evolution of the LEWIS platform to community for monitoring applications and showcasing sensors gathering real-time data is one way in which the LEWIS project and accessible intelligent sensing solutions gain exposure. This is especially true within communities with a strong need and focus on STEM education.

SMILab also collaborates with industry professionals to gain exposure on the LEWIS platform and the versatility, reliability, and accessibility they can offer to communities such as the pueblos of New Mexico (see Figure 5). Through these public and private collaborations and outreach events, LEWIS is gaining a reputation as a sensing solution equipped to help come up with solutions for the diversity of infrastructure communities face. From urban to rural communities and infrastructure, SMILab envisions that reaching out and fostering collaboration between their team and companies can help propel the project to virtually any area.

## INVOLVING HIGHSCHOOL STUDENTS

A critical component of SMILab's community outreach involves inviting students across New Mexico to attend workshops on sensing technologies and how LEWIS is at the forefront of emerging community-focused sensing solutions. From middle school students to graduate-level researchers, SMILab's educational initiatives largely involve hands-on fabrication and simulated deployments of sensors to show not only the process of creating sensors, but also how they can be effectively used in the field. These initiatives are led by members of the SMILab team under Dr. Fernando Moreu.

LEWIS workshops with STEM graduates have delved into diverse deployments and applications. These applications explore how variations of LEWIS, such as the LEWIS 1 accelerometer as shown in figure 6, can be used for many different purposes such as vibration detection and movement detection on infrastructure. The graduate students shown in figure 6 were able to fabricate the LEWIS 1 accelerometer and come up with applications of such a sensor in their STEM fields of study.

Figure 6. LEWIS 1 accelerometer class taught to graduate students.

Thanks to a growing focus on STEM education for K-12 students (see Figures 6 and 7), LEWIS classes have been very successful in engaging K-12 students in engineering, SHM, and environmental science topics. With guidance and instruction from SMILab team members, students in figure 7 fabricated the LEWIS 1 accelerometers and studied the correlation between simulated activities involving their accelerometers and the real-time data visualized on their laptops These students were not only able to understand the hardware components of the sensor, but they were also able to interpret the visualized data from each simulation. These workshops and classes are one of the many successes of the SMILab team as these initiatives show how LEWIS can be used to build collaborations and partnerships with communities and groups within the public and private sector.

Figure 7. LEWIS class taught to middle school students.

Figure 8. Components (LEWIS rainfall, sonar, and hotspot units) within a LEWIS network being prepped for deployment at a site.

## EXAMPLE DEPLOYMENTS

LEWIS network deployments are crucial in keeping LEWIS units up to date, reliable, and functional. In partnership with the Ohkay Owingeh pueblo in New Mexico, SMILab has been able to stage several SHM deployments in areas within the community that suffer from environmental risks to infrastructure such as flooding.

LEWIS units are deployed in these areas along with a singular or multiple hotspots to interconnect the units to form a LEWIS network. The number of hotspots depends on the number of units used with each hotspot interconnecting a node within the network. As shown in figures 3 and 8, in the LEWIS model 5 platform, up to two LEWIS model 5 units were fixed on top of a tripod and deployed in the field. The types of data collected depends on the type of LEWIS units within the network (i.e., rainfall, sonar, camera, etc.) and each tripod is placed in specific predetermined spots within a deployment location to gather useful data. These deployment sites and predetermined locations were chosen through collaboration between SMILab and Ohkay Owingeh with the deployments being carried out rapidly by the experienced SMILab team. Through this partnership and joint effort, LEWIS continues to evolve into sensing solutions with a strong community focus. The data acquired through these LEWIS networks allows communities such as Ohkay Owingeh to monitor rainfall, water accumulation, flooding, and infrastructure health remotely and safely.

## CONCLUSION

The involvement of the owner is critical for the advancement of effective field implementation of structural health monitoring to ensure the safety of infrastructure using sensors. Community involvement and the introduction of structural monitoring in the early stages of public education is crucial in spreading the importance of structural monitoring and cost-effective sensing solutions. LEWIS, a Low-cost Efficient Wireless Intelligent Sensor platform, was created by the SMILab team and is used effectively for such a purpose: to give communities the ability to create innovative monitoring solutions, including combating climate change and educating communities on sensors.

The ability of the LEWIS project to be an effective solution to the problems communities face is reliant on the partnerships and collaborations. Aside from the successes of current deployments in the Ohkay Owingeh pueblo, LEWIS units are consistently improving to become more reliable and self-sustaining when deployed in the field.

## REFERENCES


1. Ettouney, M., and Alampalli, S. 2011. "Infrastructure Health in Civil Engineering: Theory and Components." CRC Press, September 2011.
2. Alampalli, S. 2021. "Structural Health Monitoring for Asset Management of Highway Bridge Infrastructure," Keynote Paper, in *Tenth International Conference on Structural Health Monitoring of Intelligent Infrastructure*, Porto, Portugal (Virtual).
3. Sanei, M., Atcitty, S., and Moreu, F. Low-cost Efficient Wireless Intelligent Sensor (LEWIS) for Engineering, Research, and Education, arXiv preprint arXiv:2303.13688.
4. Murillo, J.S., Moreu, F., and Ball, M. 2021. "5th Generation Low-cost Efficient Wireless Intelligent Sensors (LEWIS 5) for Transportation," 100th Annual Meeting of Transportation Research Board, Transportation Research Board, Washington, D.C.