

## Smart buildings in action – real-time structural monitoring Barcelona’s Olympic venue “Palau Sant Jordi”



### Background

The Palau Sant Jordi is a multi-purpose indoors installation and is part of the Olympic Ring complex in Barcelona (see Figure 1). Palau Sant Jordi was opened in 1990 and is considered a masterpiece of modern architecture and engineering. Palau Sant Jordi’s roof consists of a giant, metallic web combined with glazed ceramic tiles.

Palau Sant Jordi is a multi-functional space equipped with the latest technology. It is easily and speedily set up for production as diverse as concerts, sporting events, family shows or corporate events. It is an intelligent building provided with a control centre that permits the quick and efficient management and operation of climate control, light, fresh air, sound, cameras and alarms.

With a maximum capacity of 17,960 people, the Palau Sant Jordi has a track record endorsed by 20 years of success, “where everything is possible”.

### Motivation

Very strict safety and maintenance standards are required at Palau Sant Jordi in order to avoid disasters and ensure low operational costs. A monitoring system was chosen to optimise this infrastructure’s performance while avoiding unnecessary risks. The goal of the project was to enable real-time monitoring of the loads applied to the roof’s structural system, including:

- weight applied to each individual load point; and
- load distribution and equilibrium in the entire structure.

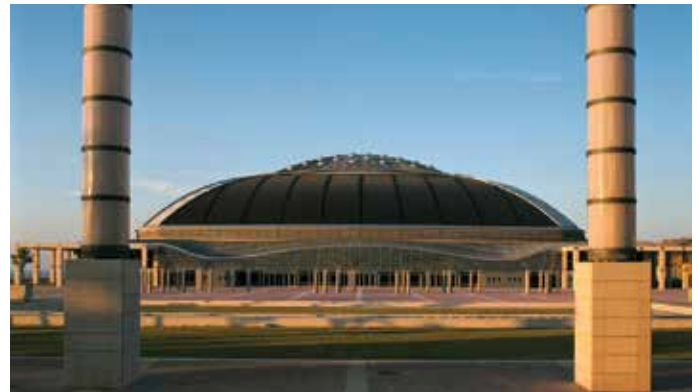
### Built Environment



### Information & Communications



Figure 1 – The Palau Sant Jordi, Barcelona, Spain



Worldsensing’s seismic monitoring solution, Loadsensing, was selected for this purpose. This system is a wireless data acquisition system for industry-compliant sensor networks of any size, applicable for engineering, oil/gas/water acquisition and CO<sub>2</sub>-sequestration purposes (see Figure 2 for examples of usage).

The system is compatible with most commonly used sensors within industry. It has dataloggers adaptable to multiple technologies (such as voltage, vibrating wire, 4-20mA, SDI-12, etc.) and sensors (such as tiltmeters, load cells, extensometers, crackmeters, piezometers, water quality probes, hydrocarbon detection, etc) in order to support periodic readings for structures.

The system monitors load distribution and structure’s equilibrium using a wireless datalogging mesh network which brings all data from the load points within Palau Sant Jordi to client’s servers; and is controlled from the administration centre and visualized on-site with high-intuitive software installed in tablets.

### Development

The Palau Sant Jordi structural monitoring system consists of 153 foil strain gauge load cells (S-type) to control all load points in the structure, that are read every 5 seconds by 21 wireless multi-channel dataloggers (see Figure 3).

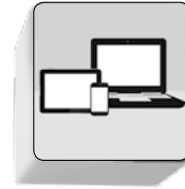


Figure 2 – Example usage of Loadsensing in engineering, seismic and other applications

**LOADSENSING FEATURES**

- ULTRA LOW POWER CONSUMPTION UP TO 4 YEARS OF UNATTENDED OPERATION
- TRUE MULTI-HOP CAPABILITIES
- A SINGLE NETWORK WITH UP TO 100 NODES
- LICENSE EXEMPT 2.4 GHz ISM BAND
- NODE TO NODE UP TO 200M RANGE

**IMMENSE DATA SAVING**  
Reducing amount of network

**SMART NETWORKING**  
Real time low latency smart dynamic communication paths, sending readings through any route in the network

**LONG AUTONOMY**  
6-7 years for sensors every 20 min

**NO BATTERIES**  
Engineered and tested for extra mechanical, temperature resistance, lightning and water protection

**PLUG & WIRE**  
Plug the sensors and start visualizing, configuring your sensor network through a friendly web portal displaying real time and historical data

**EASY POSE & PLUG**  
Sensor connects through user friendly connector

**STRUCTURES - GEOTECHNICS**

- Canals
- Dams
- Buildings
- Subways & Highways
- Foundations
- Shape stability
- Land slides
- Lateral path support structures
- Soil mechanics

**DIGITAL OILFIELDS**

- Pipelines
- Hydratation detection
- Oil detection
- Sea detection
- Terminal & tank monitoring

**ENVIRONMENT**

- Water quality
- Air pollution
- Fermentation, Soil moisture
- Chlorophyll pigments
- Vegetation

**INDUSTRY**

- Plant pressure and temperature
- Structures
- Waterflow
- Electricity
- Chemical

**LOADSENSING INTRODUCES THE 1<sup>ST</sup> WIRELESS SENSOR SYSTEM COMBINING USE WITH INDUSTRY PERFORMANCE**

**LE DATA OFFERS REAL TIME DATA OF 100% OF THE SENSORS. THE MAINTENANCE PROVIDER REMOTE MONITORING REAL TIME DATA OF 100% OF THE INFRASTRUCTURE**

**LOADSENSING SIMPLY INSTRUMENTATION DEPLOYMENT, MAINTENANCE, INSTALLATION AND MAINTENANCE COSTS**

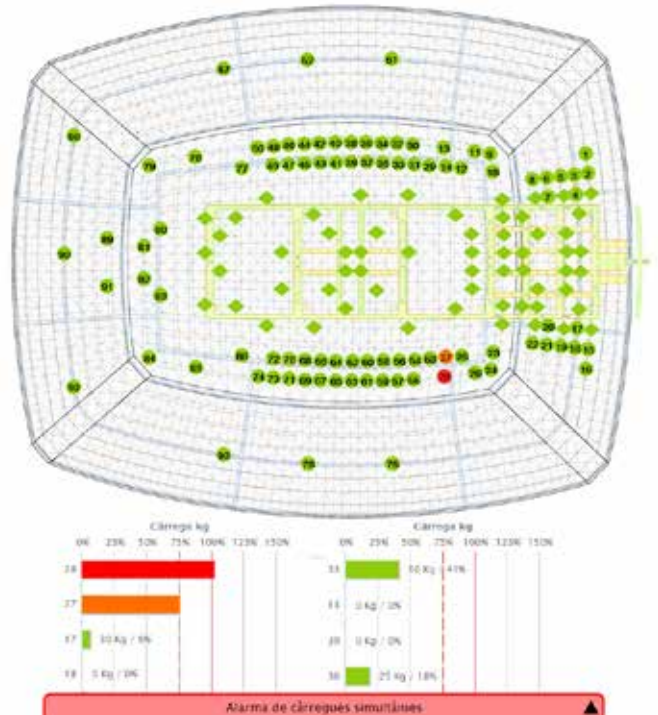
**WIRELESS MONITORING KILLS 2 BILLS IN THE REAL INSTRUMENTATION WORLD**

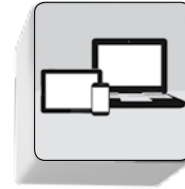
**SMART AUTO CONFIGURED SENSOR NETWORKS**

**BIDIRECTIONAL COMMUNICATION FOR REAL TIME CONSUMPTION CAPABILITY**

**ROBOT EQUIPMENT READY FOR HARSH ENVIRONMENTS**

Figure 3 – Interior view of Palau Sant Jordi and structural sensor map





The wireless system creates a mesh network to communicate readings to the 2 high-capacity gateways, where all data is stored, processed and passed on to the client's and company's own servers for 24/7 management and control. The company's Websensing web platform and tablet app provide the software to display the load state and warning when a single load point or the structure's equilibrium exceeds its maximum.

The main technical benefits for application of the system include:

- no cabling needed, saving expensive installation and maintenance.
- true wireless mesh network delivering data 24/7 from field to control.
- remote assessment allowing for the prevention of accidents and associated costs.
- alarm system to prevent structural stress and other risks.
- robust and reliable solution, offering longevity within harsh environments.
- easy to install, plug and use; intuitive free web software.

However, the design of the industry-compliant wireless datalogger system has been significantly more challenging than anticipated:

- From a technical point of view, the datalogger had to obey stringent requirements on resolution, sampling signal to noise ratio and sampling frequency, packaging, data delivery reliability, etc.
- From a business point of view, the project team had to bridge the long sales cycles inherent to these business-to-business (B2B) markets and "educate" the very traditional

market of instrumentation that wireless Industrial IoT solutions, coupled into Big Data platforms, are indeed a major competitive factor in the industry.

## Results

The Loadsensing installation has not only saved over 4km of cables, but most importantly, it has given the client peace of mind, thanks to its alarm capacities and real-time status monitoring for Palau Sant Jordi's structure. Over the last 18 months since installation, the system has delivered over 1 billion precise readings in real-time, at a sampling rate of 5 second intervals.

In that period, the system has 'watched over' events such as the X Games, the FINA World Championships and the World Handball Championship, among other events (concerts, exhibitions, trades, conferences).

## Next steps

The Palau Sant Jordi project – as well as many other international projects Loadsensing has been deployed in, demonstrates that a European SME can successfully leverage the knowledge of its founders and the ongoing learning curve of real-world project experience to build capacity for strategic projects worldwide. Future opportunities range from providing turn-key solutions for end customers, (from large construction firms to energy companies and other) to providing support across all phases of an IoT project, including design, consultancy, equipment provision (including hardware and software), installation, permanent follow-up maintenance and data analysis.

## Acknowledgement

Dr Ignasi Vilajosana (Chief Executive Officer), Jordi Paretas (VP Industrial Internet) and Marta Comas (VP Marketing) work at Worldsensing, Spain. Prof. Mischa Dohler sits on the Board of Directors of Worldsensing, is Chair Professor, King's College London and is also an IEEE Fellow & Distinguished Lecturer and Editor-in-Chief of *Transactions on Emerging Telecommunications Technologies*.

Worldsensing was founded in 2008 in Barcelona, and is based in London and Barcelona. The company is a market leader in innovative wireless machine-to-machine (M2M) and Internet-of-Things (IoT) technologies. It currently (2015) employs more than 40 staff. Its core expertise is in providing sensing and machine-to-machine technologies and services to specific industry verticals. It has two product portfolios: Smart Traffic solutions for Smart Cities and Heavy-Industry Monitoring solutions.