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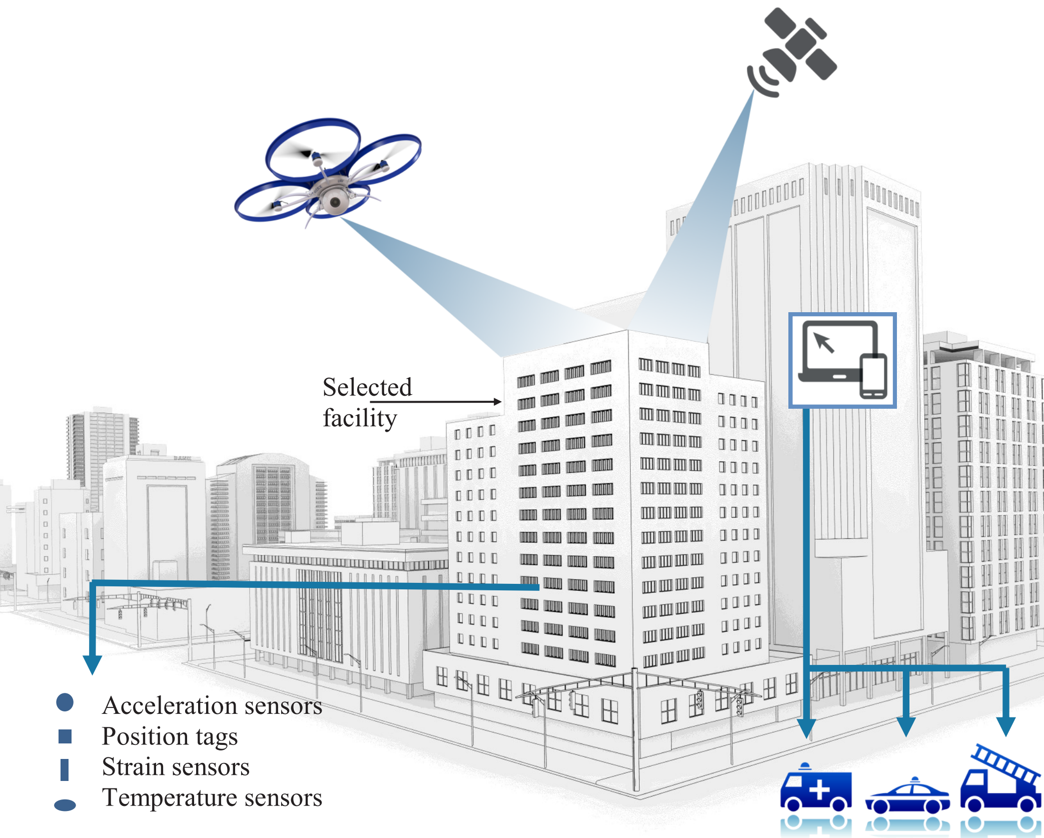
RECONASS Newsletter

Reconstruction and REcovery Planning: Rapid and Continuously Updated COnstruction Damage and Related Needs ASSessment



In this issue

Editorial P.1
The RECONASS system P.2
The Local Positioning System P.4
The Integrated Sensing Solution for Constructed Facilities P.4
3D Modelling, Photogrammetry and Disaster Response P.5
The Communication Module P.7
Monitoring-Based Assessment of the Structural And Non-Structural Components of the Monitored Building. Damage, Loss and Needs Assessment P.8
Post Crisis Needs Assessment Tool in Regards to Construction Damage and Related Needs P.9
News and Events P.9
Consortium P.10

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no [312718]

Project facts

DURATION
42 months

TOTAL COST
5,48 million euro

REQUESTED EU CONTRIBUTION
4,26 million euro

Editorial

Welcome to the second newsletter of the RECONASS project.

RECONASS is a European 7th Framework project funded under the SEC programme (grant agreement No. 312718).

The main objectives of the project consortium are: (a) to provide a 'smart' structural monitoring system permitting a reliable and ongoing assessment of the state of structures hit by earthquakes, explosions and other causes, (b) in case of extended events to use the above detailed assessment of monitored facilities for the speedy calibration of satellite and oblique serial photography of the damaged area and (c) based on input from (a) and (b) above develop a post-crisis needs assessment tool in regards to construction damage and related needs.

The project officially launched its activities in December 2013. During the first 7 months of the project the partners identified an extended group of end-users, derived user requirements and based on these determined the system architecture. Subsequently, the development process of the RECONASS components has started.

In this issue you will find an overview of the whole RECONASS system and the progress, so far, in the development of its various components.

Angelos Amditis

Project Coordinator

The RECONASS system

The RECONASS system comprises: a compact and highly energy efficient local positioning system and a set of strategically placed strain, acceleration and temperature sensors all of which send measurements to the base station through a robust, secure, intelligent and resilient communication module. Additionally, a remote sensing approach complements the aforementioned data extraction methodologies, using air borne and space borne systems. Last but not least, capitalising on the data derived from all above systems, subsequent data fusion and overall structural and non-structural assessments are enabled within an interoperable Post Crisis Needs Assessment Tool in regards to Construction Damage and related Needs.

Following below is a more detailed description of the RECONASS system:

1. This project develops a **monitoring system** for constructed facilities (implemented in this work in the case of reinforced concrete buildings) that provides a near real time, reliable and continuously updated assessment of the structural condition of the monitored building under operating, seismic, blast, impact or fire loading.

For the above, tags for local positioning, strain gages, accelerometers and temperature sensors are used as shown in Fig. 1

The tags for local positioning are embedded in the structural elements to provide real-time information on their location wirelessly and automatically. After a major disaster, such as an explosion, where some structural members will be seriously deformed or change position, the location of the above tags is being used to assess the structural system that has emerged from the disaster.

Strain and acceleration sensors are used to assess the structural condition of the building after an earthquake, blast and impact loads, while strain sensors are used to assess the structural condition of the monitored building under operating loads (see Fig. 2).

2. The **structural assessment** provides input for the real-time assessment of the condition of the non-structural building elements, while the assessment of both structural and non-structural elements provides input for the assessment of physical damage, loss of functionality, direct economic loss and needs of the monitored facilities in terms of funds, time and construction materials and manpower (see Fig. 3).

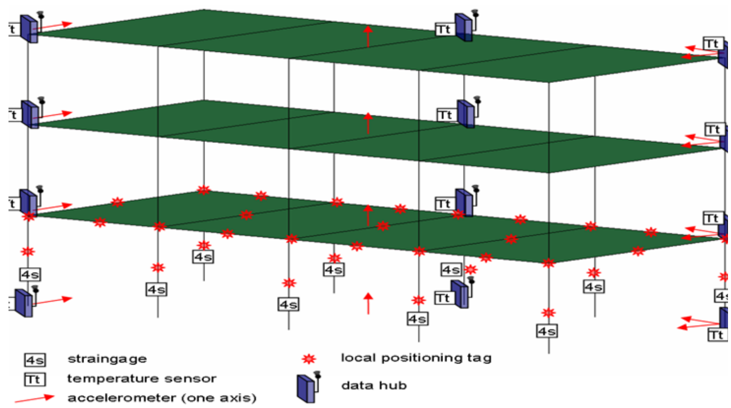


Figure 1. The RECONASS Monitoring System (not all tags are showing)

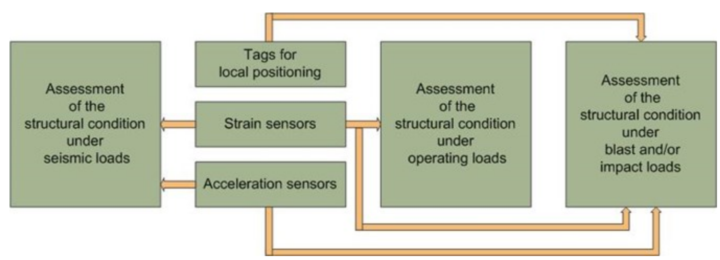


Figure 2. Type of Required Input for the Assessment of the Structural Condition under Operating, Seismic, Blast and Impact Loading

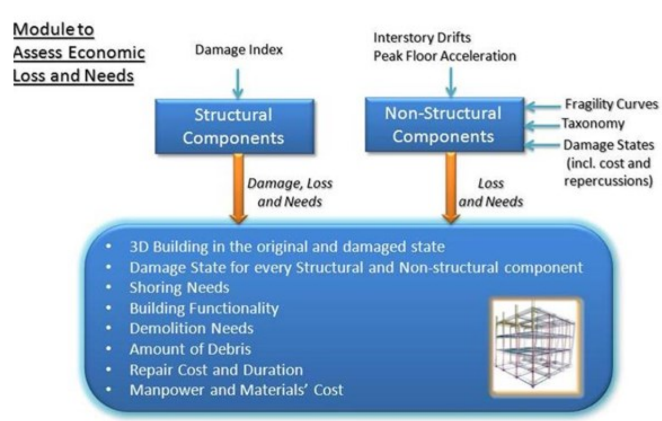


Figure 3. Assessment of Economic Loss and Needs

3. Seamless interoperability among heterogeneous **communication networks** is provided in order to secure that the required information from the monitored building can reach, in near real time, the base station even under difficult conditions, such as a post-earthquake situation (see Fig. 4).

4. The detailed monitoring described above is only economical for selected facilities that are essential for response and recovery or facilities that have a high value as a target for terrorist attacks. In case of spatially extended events, in order to assess the physical damage in the whole affected area, the detailed assessment of damage in the monitored facilities is used for the speedy local calibration of **satellite and oblique aerial photography** dramatically reducing the required time to inform the post disaster/crisis needs assessment process and provide data for reconstruction efforts.

5. All of the above are part of the RECONASS **Post-Crisis needs assessment tool** in regards to Construction Damage and related Needs (PCCDN). This tool enables fusion of external information, allows for future expansion of the system, provides international interoperability between relevant programs and support the collaborative work between units involved in reconstruction and recovery planning (see Fig. 5).

ENSURE SYSTEM RELIABILITY

Testing and validation

All functionalities and the overall assessment process and results will be preliminary tested on a **component basis within a laboratory environment** to be ultimately validated and benchmarked **on the field** after detonating several **blasts on a ½ scale pilot building**.

The last test is expected to prove the **RECONASS concept as a reliable and innovative structural health monitoring system** capable of being used in both earthquakes and explosions providing at the stakeholders a rich set of assessment data in regards to the affected structure's condition.

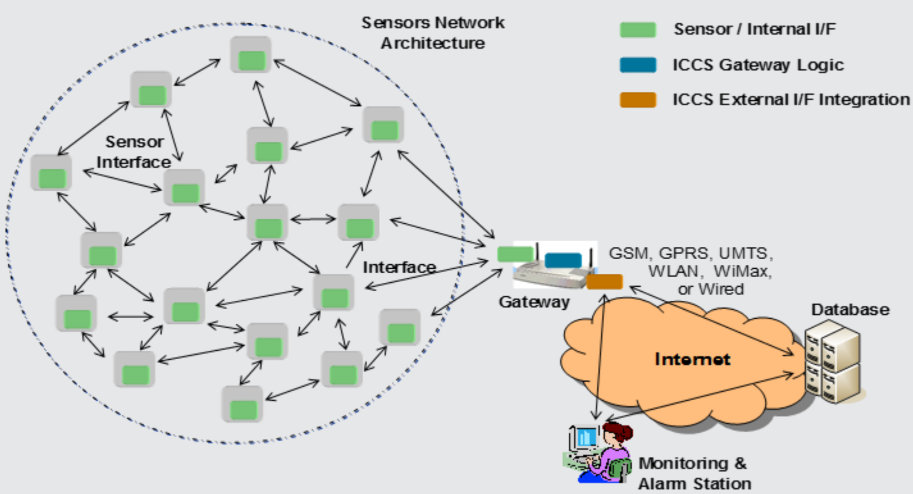


Figure 4. RECONASS Architecture of Wireless Mesh Communication Network

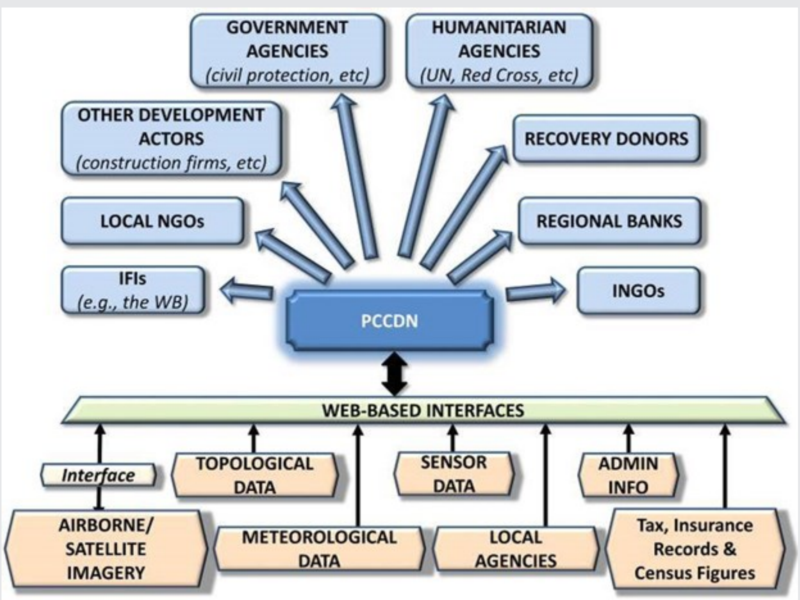
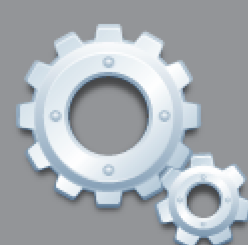


Figure 5. Overview of the PCCDN Tool



The Integrated Sensing Solution for Constructed Facilities

Information gathered from a structure during critical events that affect its structural and non-structural components will help the relevant stakeholders to further assess technical issues related to damage estimation and possible retrofit and repair.

In particular, the RECONASS Integrated Sensing Solution for Constructed Facilities, in addition to the tags of the LPS placed as described in the previous section, will also include temperature sensors, accelerometers and strain sensors. Three strain sensors will be attached on the reinforcing bars at 3 of the corners at the bottom cross section of the columns at the ground floor. One 1 Dimensional (D) and one 2D accelerometers will be installed at two extreme points of every slab, including the basement slab. Additionally, one 1D accelerometer will be installed in the largest span in every floor to enable monitoring out of plane behaviour, especially under explosive loading. Last, 2 temperature sensors are expected to cover each floor of the building installed at two extreme points. (see Fig. 1)

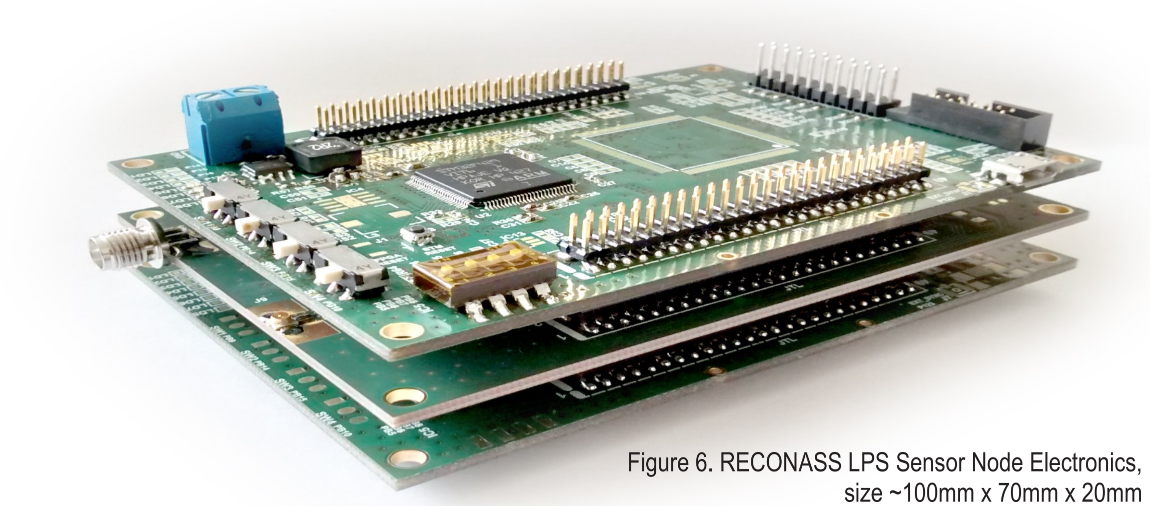


Figure 6. RECONASS LPS Sensor Node Electronics, size ~100mm x 70mm x 20mm

The Local Positioning System

The local positioning system (LPS) in the RECONASS project has the task to sense and retrieve the operational conditions of the structure by measuring the displacement of structural elements inside the building.

In order to be suitable for structural health monitoring (SHM) a precise LPS needs to be designed. The system is specified with a precision of less than 10 cm, which is the standard deviation of a displacement measurement.

The LPS to be designed for RECONASS consists of sensor nodes or tags, which are either attached or embedded in slabs, beams, shear walls and columns. Certain nodes become dedicated reference nodes, e.g. those mounted at the edges of the building. The reference nodes are assigned a predefined position, either by using the building outline as a reference frame, by means of GPS or by a total station which is an optical measuring device used to determine landmarks and measures during building construction. The reference nodes then act as anchors. The nodes can be mounted in a box inside the wall attached to the beams and columns of the building. Furthermore, there are coordinator nodes, which are connected to a certain number of LPS sensor nodes and which coordinate positioning signals, calculate the position of each node relative to the anchors and interface to the rest of the RECONASS monitoring system. The coordinators can be installed on a per-room basis, where it connects to a certain number of nodes.

A photograph of the sensor node electronics is presented in Fig. 6. It consists of three stacked circuit boards. The top board contains the digital processing and control components, performing the positioning algorithms. The middle board holds the analogue radio frequency (RF) components and the lowest board implements the interfacing with the RECONASS monitoring system.

The RECONASS tag and coordinator hardware uses an application specific integrated circuit (ASIC) for transmitting, receiving and processing RF localization signals in the bands at 2.4 GHz and 5.8 GHz. The localization scheme will be based on a secondary frequency-modulated continuous wave (FMCW) radar. The RECONASS system aims for an increased level of component integration, which will be accomplished by adding most of the signal processing components to the ASIC. A high level of integration allows small form factors, low power consumption and low cost in mass fabrication. A micrograph of the ASIC is shown in Fig. 7. It incorporates the most important building blocks such as low noise amplifier (LNA), a frequency mixer, voltage-controlled oscillator (VCO) and phase-locked loop (PLL) which can serve the two frequency bands, a base band variable gain amplifier (VGA) and power amplifier (PA) drivers.

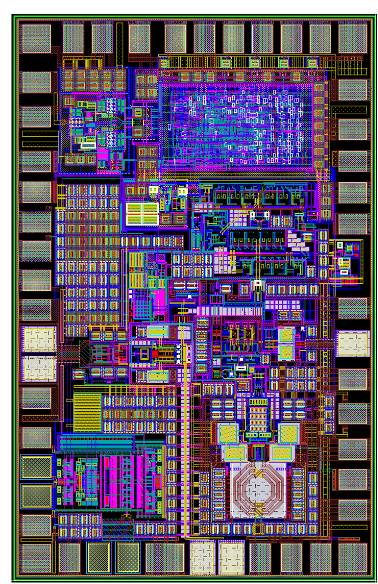


Figure 7. Layout of RECONASS ASIC, size ~1 x 2 mm²

3D Modelling, Photogrammetry and Disaster Response

Remote sensing based structural damage assessment is one of the sub-systems of the RECONASS system. The primary function of this sub-system is to provide very detailed and element-specific damage assessment for the monitored and neighbouring buildings, using the images captured by an Unmanned Aerial Vehicle (UAV). UAVs are highly flexible in capturing images with specific characteristics, such as high frame overlap, high spatial resolution, and with multiple camera views, all of which are mandatory for photogrammetric processing and 3D modelling. The UAV-captured images are the only input required by this sub-system. From those images, the sub-system automatically generates a so-called 3D point cloud of the scene. Using the images and the 3D point cloud, the sub-system identifies the completely collapsed and intact buildings in the scene. The intact buildings are further analysed for the presence of damage evidences such as cracks, spalling and breakage along every exterior element of the building for detailed damage assessment. Also, the debris and rubble piles around the building are detected and quantified. The methodologies for performing various tasks, such as detection of collapsed and intact buildings, debris mapping and identification of broken elements of the building, have been largely developed. The methodologies for other tasks, such as detailed crack detection, debris volume quantification, identification of inclined elements and overall damage classification, are still being developed. The detected damage evidences for the monitored building will be annotated on a pre-event CAD model of that building. This will be synergistically used with the wireless sensor network (WSN) based damage information provided by other sub-systems in RECONASS for the improved level of assessment and also for the validation and calibration of the damage assessment of one technology with another.

Follow-up RECONASS

The end user group is invited to follow-up the RECONASS process during the project's lifetime via the RECONASS homepage (www.reconass.eu) as well as via twitter and LinkedIN and to contribute within all in all three RECONASS end-user workshops.

www.reconass.eu

#Reconass

RECONASS group

WORK FLOW

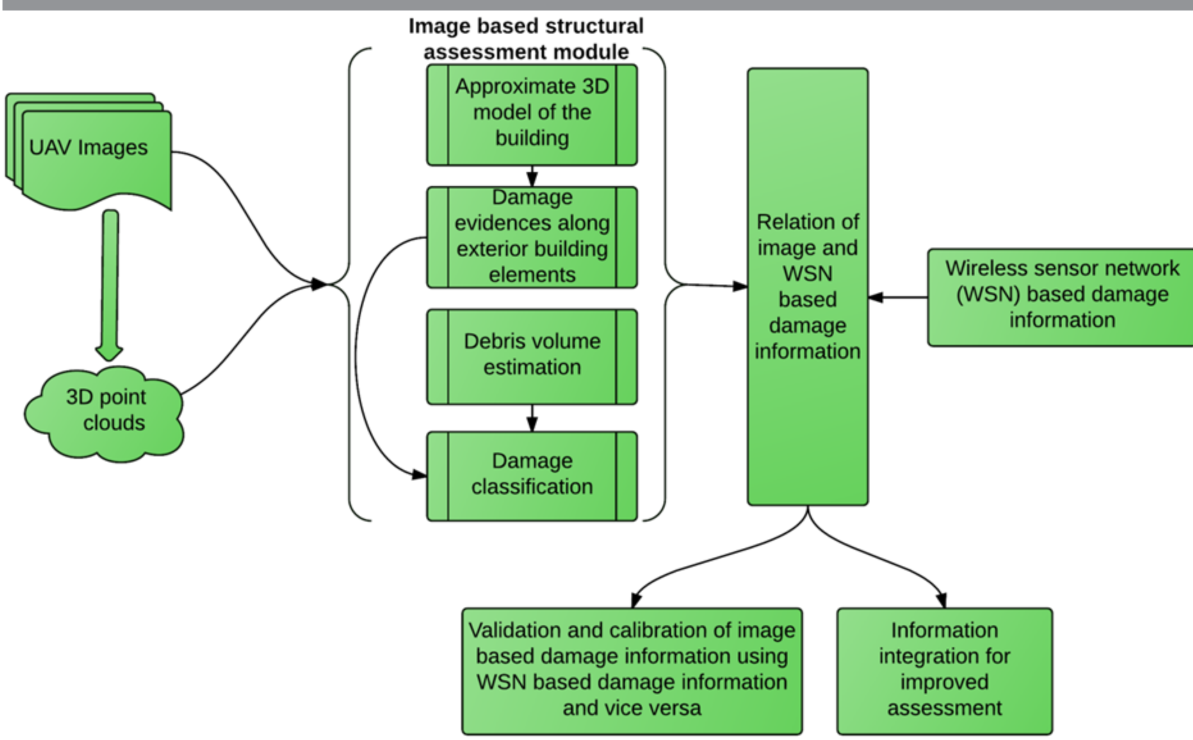


Figure 8. Overall Work Flow of the Sub-System

Sample results

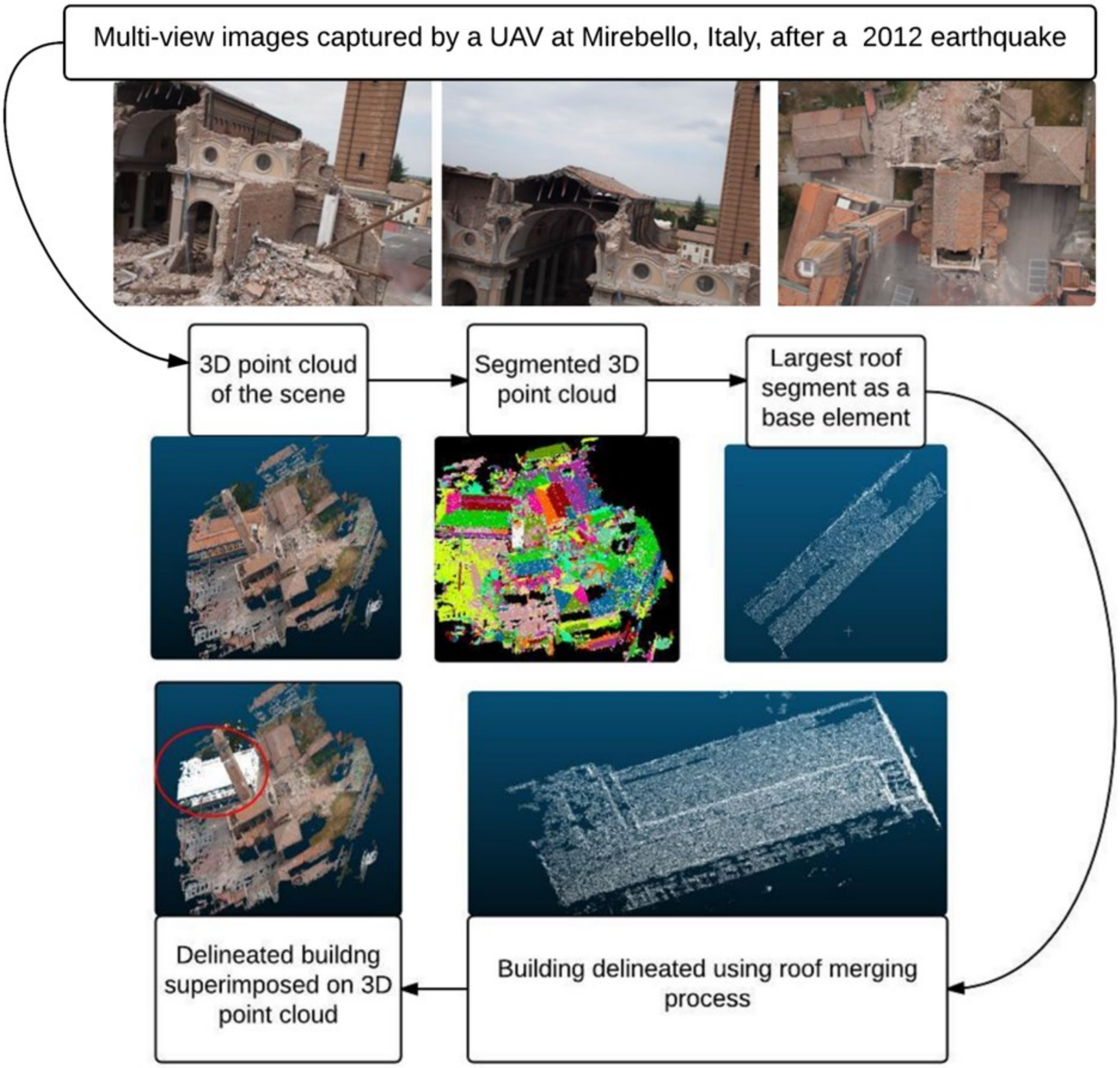


Figure 9. Example of Building Delineation Process

Figure 10. UAV Image Taken after the 2012 Mirabello Earthqake (left); Damaged Regions Mapped by our Method in Red Task (right)

The Communication Module

The communication architecture includes all sensorial components and the respective communication means including network configuration and topologies. The topologies take into consideration the tags, the strain sensors, the accelerometers, the temperature sensors, the data hubs, the gateway and the PCCDN tool as the measurements need to be transmitted from the sensorial devices up to the platform to be operated by the end users (i.e. PCCDN tool). The particular network components to be deployed and the software to be developed to cover the expected RECONASS functionalities in regards to intelligent, robust and resilient communications have been accurately captured. At the same time the development process that involves both hardware and software of the communication module has been initiated and divided in four distinct layers, namely Security, Smart Routing, Sensor Network Management and Data Sum and Management layer. All the communication software modules, including those already developed and those to be further developed, are produced in an agile mode, as stand-alone executables so that to allow for provisional testing and evaluation as well as to permit smooth, seamless, risk-free integration to the overall system.

As it can be seen in Fig.11, the overall communication architecture can be divided into three separate networks, a wide area (WAN), a local area (LAN) and a local sensor network (LSN). In the former, middleware logic will be implemented to support secure connectivity and seamless interoperability among heterogeneous networks such as GSM, UMTS, WLAN, Wi-MAX, LTE, ADSL, etc The LAN will interconnect the gateway with the data hubs, both wirelessly and wired in a mesh architecture utilizing Wi-Fi and IEEE 802.3 variants..The LSN contains the information retrieved from the LPS and the various sensors (accelerometers, strain and temperature sensors) which will be forwarded to the gateway through wireless and wired interfaces through 802.15.4 variants (e.g. Zigbee Pro.), IEEE 1284 variants and wired general purpose input/output (GPIO).

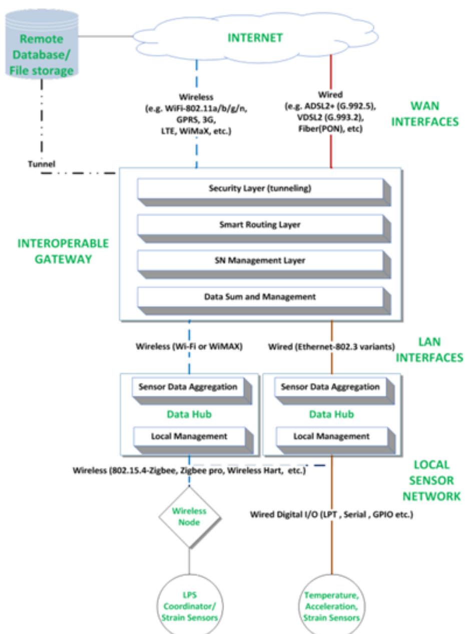


Figure 11-High level overview of the communication architecture

Sensors' design criteria

For the strain, acceleration and temperature sensors the design criteria have been specified and the types of sensors to be deployed have been precisely described including their functionalities in regards to the values of strain, acceleration and temperature that will retrieve; the frequency of performing these measurements and the power consumption options.

The following table provides an overview of the specifications to be satisfied:

Specifications summary		
Strain sensors	Acceleration sensors	Temperature sensors
Strain measuring capacity Q ±2.500 μ strains have been specified; but this may be damaged and need replacing after a strong earthquake or blast motion. A strain sensor of Q = ±25.000 μ strains specification may be required and should not require replacement) Measurement accuracy: 50 μ strains	Frequency interval : 0.2 to 10 Hz (Period internal : 0.1 to 5 sec) Acceleration measurement capacity: ±5g Measurement accuracy: 0.005g Recording capacity: 50 records per second Time synchronization for the totality of accelerometers is required. Triggering: Through Software on continuously recorded data	Downview area up to 250 m²: 3 sensors Downview area 250 to 500 m²: 6 sensors Downview area over 500 m²: 10 sensors Temperature measurement capacity: 0 to 1500 ºC Measurement accuracy: 10 ºC

Monitoring-Based Assessment of the Condition of the Structural And Non-Structural Components in the Monitored Building. Damage, Loss and Needs Assessment.

Monitoring–Based Structural Assessment of the Structural Elements

The structural condition of the structural elements and the overall monitored building is assessed under the following conditions:

Operating conditions: The structural assessment is based on the records of strain gouges installed at the bottom cross sections of the building in the ground floor. Linear structural analysis procedures are applied resulting in the estimation of the actual values of the live loads, the differential settlements of the foundations and the safety factors at the critical cross sections for the totality of the structural members.

Earthquake action: The structural condition is assessed based on the records of two 2-D accelerometers per floor that provide the displacement time-histories of the floors, the estimation of the damage index for the totality of the structural members and the global instability index for the stories and the building.

Explosion event: The structural assessment is based on the records of displacement of the local positioning tags installed at the midpoint of the spans of the structural members that permit the evaluation of the reduced stiffness of the members situated in the vicinity of the explosion and the effect of the ensuing oscillations to the totality of the structural members. The latter being estimated by applying the module for the earthquake action based on the records of the accelerometers.

Fire event: The structural assessment is based on the records of the temperature sensors spread throughout the fire compartments of the floors, permitting the estimation of the temperature time-history for each one of the members, their effect on the material properties, the analysis of the structure and the estimation of the safety factor for the totality of the structural members.

Damage in non-structural elements under the 4 conditions above. Loss Analysis.

Most non-structural elements, unlike structural elements, are not directly affected by the ground shaking in an earthquake, but rather are affected by motion or shaking of the structure to which they are attached or upon which they are supported. Similarly in the case of blast or impact, with the exception of the non-structural components that are directly hit, or are attached to structural components that are directly hit, the rest of the non-structural components are affected by the motion or shaking of the structure to which they are attached or upon which they are supported. In this case their damage level is a function of the response of the building structure at the points of their attachment to structural components.

Accordingly, the assessment of damage to non-structural elements is based on the results of the structural assessment module. In particular the structural module derives parameters, such as floor acceleration or peak interstory drift, to which the non-structural components are sensitive. On the basis of the values of the latter parameters, the damage state of the non-structural components is assessed.

In case of fire, the damage states are based on input from the temperature sensors on time of exposure and maximum temperature.

Emphasis has been placed on exterior, non load bearing, masonry walls, prevalent in reinforced concrete buildings in the seismic prone countries of Europe and elsewhere (e.g., in Australia or New Zealand), because the assessed damage of these walls will be used to calibrate satellite based damage maps after an earthquake. Here, using input from the structural assessment on the acceleration and velocity at the four corners of the wall, the seismic damage of these walls has been assessed.

A taxonomy of all structural and non structural components has been designed to facilitate damage analysis (estimation of physical damage as a function of structural response), as well as direct loss analysis (repair type, repair cost and duration as a function of damage).

To facilitate collaboration this taxonomy is consistent as much as possible with existing building taxonomies developed for national use (e.g., in the (US) ATC-58 project) or for international use (e.g., the GEM building taxonomy).

To assess damage and loss for each of the items in the taxonomy the following steps are followed:

The damage state of the structural elements is based directly on their structural assessment, while, as mentioned above, the damage state of non-structural elements is assessed indirectly based on input of relevant parameters from the structural assessment of the structural elements to which they are attached or upon which they are supported.

Based on the damage state of the various building elements the building functionality, amount of debris and repair needs are determined, the latter in terms of funds, manpower, materials and time (see Fig. 12 for non-structural elements).

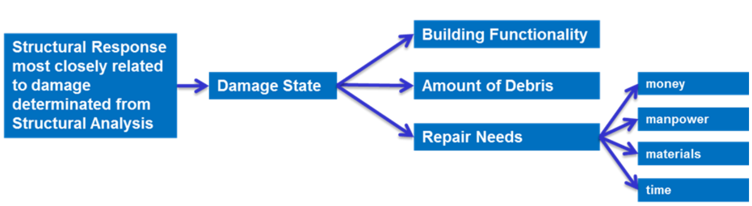


Figure 12 Overview of the Estimation of Repair Needs, Debris and Functionality in the Case of Nonstructural Components.

Post Crisis Needs Assessment Tool in Regards to Construction Damage and Related Needs (PCCDN Tool)

The PCCDN Tool acts as an intelligent intermediary between the user and the results obtained from the various Work Packages. It:

- is based on web sensors and a Service Oriented Architecture (SOA)
- adopts open architectures and
- achieves interoperability

It provides users with 3D representations of the monitored building based on a CAD model and the location of this building based on Google Earth.

Service oriented architecture provides the framework for serving distributed communication, allowing the smooth integration of disparate information into the system.

The system can be continuously fed with information:

- from the wireless sensors on the structure,
- from the monitoring–based structural assessment module on the damage state of the structural elements and the overall structure,
- from the damage, loss and needs assessment module on repair needs, debris and functionality of the monitored building,
- from the remote sensing via UAV on collapsed and intact buildings, presence of damage, debris and rubble piles around the building.

The PCCDN tool will be extended to integrate additional information, such as input from local agencies, and meteorological data.

In order to make integration with sensors more efficient, the OGC Sensor Web Enablement architecture (SWE) Sensor Observation Service Standard has been followed as it defines an interface for accessing sensor data and metadata.

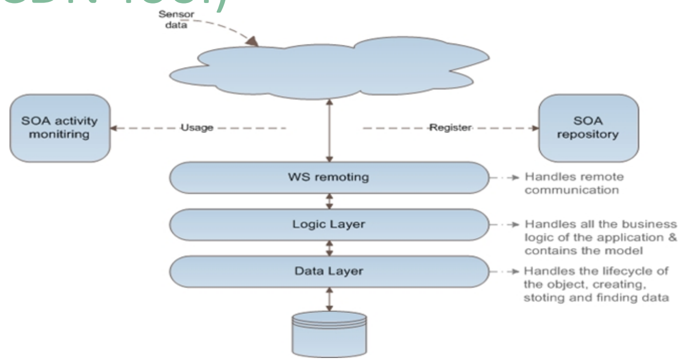


Figure 13. Overview of the PCCDN Tool

News and Events from November 2014 to April 2015

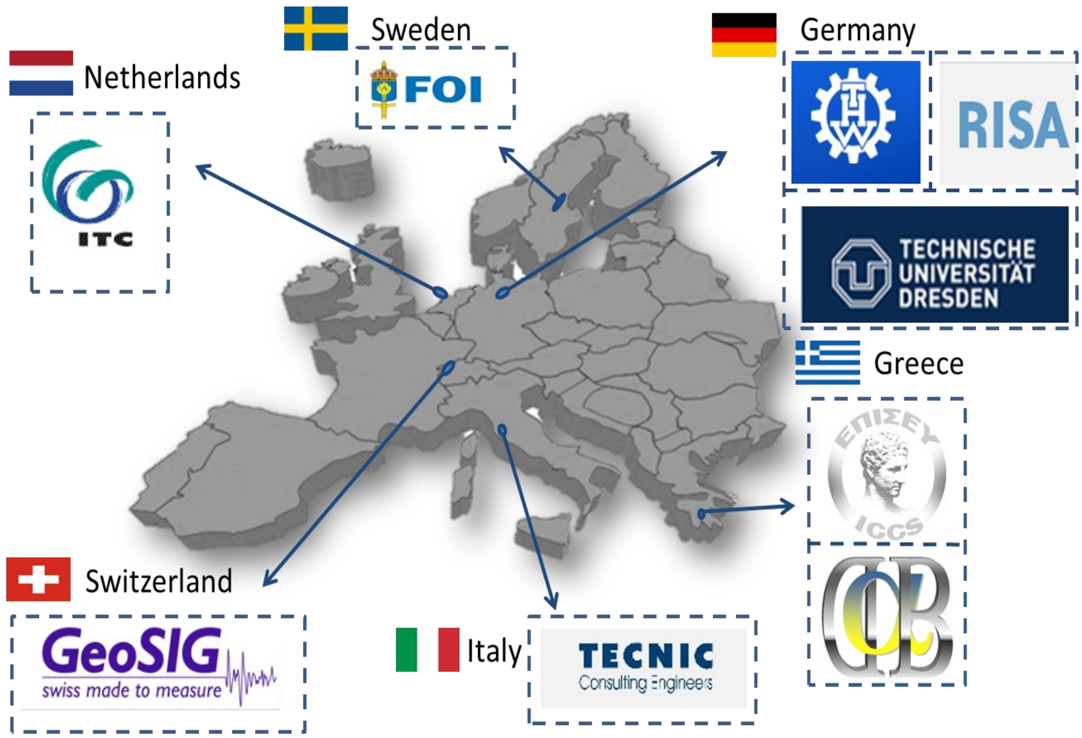
Scientific Presentations/Publications

- K. Vierhuss-Schloms, 'RECONASS', The 9th SEcurity Research Conference 'Future Security' organized by Fraunhofer Group for Defence and Security VVS, that took place on Sept. 16-18, 2014 in Berlin.
- N. Joram, R. Wolt, B. Linner and F. Ellinger, 'Concurrent 2.4 and 5.8 GHz Dual Band Power Amplifier for FMCW Radar Systems,' Int. Symp. on Intelligent Signal Processing and Communication Systems (ISPACS), Dec. 1-4, 2014, Kuching, Sarawak, Malaysia, pp. 279-282.
- N. Joram, J. Wagner, E. Sobotta and F. Ellinger, 'Fully Integrated Wideband sub-10 GHz Radio Frequency Front End with Active Matching,' IEEE PRIME 2015 Conference, June 29-July 2, Glasgow, Scotland.
- B. Al-Qudsi, M. El-Shennawy, Y. Wu, N. Joram and F. Ellinger, 'A Hybrid TDoA/RSSI Model for Mitigating NLOS Errors in FMCW Based Indoor Positioning Systems,' IEEE Prime 2015, June 29 to July 2, Glasgow, Scotland.
- E. Edwan, M. Gunia, B. Al-Qudsi, N. Joram and F. Ellinger, 'Smart Wearables Combined with Smart Phones for Pedestrian Navigation Applications,' Int. Symposium on Fundamentals of Electrical Engineering (ISFEE), Nov. 28-29, 2014, Bucharest, Romania.
- E. Edwan, M. Gunia, B. Al-Qudsi, N. Joram and F. Ellinger, 'Smart Wearables Combined with Smart Phones for Pedestrian Navigation Applications,' 12th Workshop on Positioning, Navigation and Communication 2015 (WPNC' 15), March 11-12, Dresden, Germany.
- E. Erwan, M. Bourimi, N. Joram, B. Al-Qudsi and F. Ellinger, 'NFC/INS Integrated Navigation System: The Promising Combination for Pedestrians' Indoor Navigation,' Int. Symp. on Fundamental of Electrical Engineering (ISFEE) 2014, Nov. 28-29, 2014, Bucharest, Romania, pp.1-5.
- B. Al-Qudsi, E. Edwan, N. Joram and F. Ellinger, 'INS/FMCW Radar Integrated LOcal PLanning POsitioning System,' 2014 DGON Inertial Sensors and Systems (ISS) Symp. Gyro Technology, Sept. 16-17, Karlsruhe, Germany, p. 17.
- A. Vetrivel, M. Gerke, N. Kerle, G. Vosselman, 'Identification of damage in buildings based on gaps in 3D point clouds from very high resolution oblique airborne images', Journal of Photogrammetry and Remote Sensing, 105 (2015) , pp. 61-78.
- A. Vetrivel, M. Gerke, N. Kerle, G. Vosselman, 'Segmentation of UAV-based images incorporating 3D point cloud information', PIA-15: Photogrammetric Image Analysis Joint ISPRS conference proceedings, 25-27 March 2015, Munich, Germany. ISPRS Archives, Vol XL-3/W2, 2015. pp. 261-268.

Presentations in Events

The RECONASS consortium was invited to join a workshop initiated by the BERISUAS cluster in Woensdrecht, NL on 6 November 2014. (http://www.mirg.eu/wp-content/uploads/2014/10/Berisuas-draft-program-.pdf) ITC attended in this meeting that brought together all kind of experts and users in the field of UAS.

Consortium



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RECONASS Newsletter

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