RECONASS

7th Framework Programme

FP7-SEC-2012.4.3-1

Next Generation Damage and Post-Crisis Needs Assessment Tool for Reconstruction and Recovery Planning

Capability Project

State-of-the-Art of Assessment Tools and preliminary user requirements

Deliverable No.	D1.1		
Workpackage No.	WP1	**Workpackage Title**	User Requirements and System Architecture
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Status	Final		
Version No.	V1.00		
File Name	'RECONASS_D1.1_State_of_the_Art_of_Assessment_tools_and_preliminary_user_requirements_V1.00.doc'		
Delivery Date	30 June, 2014		
Project First Start and Duration	Dec. 1, 2013; 42 months		

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

DOCUMENT CONTROL PAGE

Title		
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Format	Text-MS Word	
Language	en-UK	
Work Package	WP1	
Deliverable Number	D1.1	
Due Date of Delivery	28/02/2014	
Actual Date of Delivery	30/06/2014	
Dissemination Level	PU	
Rights	RECONASS Consortium	
Audience	☒ public ☐ restricted ☐ internal	
Revision	V1.00	
Edited by	Michael Markus, THW	
Status	☐ draft ☒ Consortium reviewed ☒ WP leader accepted ☒ Project coordinator accepted	

REVISION LOG

Version	Date	Reason	Name and Company
V 0.01	07/01/14	Initiation	Evangelos Sdongos (ICCS)
V 0.02	20/01/14	Modification/extension	Michael Markus (THW)
V 0.02	10/02/14	Modification, input from all partners	Michael Markus (THW)
V 0.03	16/04/2014	Modification/definition/clarification	Michael Markus (THW)
V 0.04	13/05/2014	Modification/definition/clarification	Michael Markus (THW)
V 1.00	30/06/2014	Modification/definition/clarification/reviewers' comments incorporated and finalisation of deliverable	Michael Markus (THW), Evangelos Sdongos (ICCS)

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ABBREVIATIONS AND ACRONYMS

ABBREVIATION	DESCRIPTION
DEC	Disasters Emergency Committee
EC	European Commission
GIS	Geographic Information Systems
FEMA	Federal Emergency Management Agency (US)
GDACS	Global Disaster Alert and Coordination System
GSM	Global System for Mobile Communications
HAZUS	FEMA's Methodology for Estimating Potential Losses from Disasters
IASC	Inter-agency Standing Committee (UN)
IRP	International Recovery Platform
NATF	Needs Assessment Task Force
NGO	Non-governmental organisation
OCHA	Office for the Coordination of Humanitarian Affairs (UN)
PDNA	Post Disaster Needs Assessment
UAV	Unmanned Aerial Vehicle
UNDAC	United Nations Disaster Assessment and Coordination team
UNDP	United Nations Development Programme
UNOSAT	United Nations Operational SATellite (UNITAR)
WB	World Bank
WFP	World Food Programme
WLAN	Wireless Local Area Network

GLOSSARY OF TERMS

Term	Definition
ATC-58 Project	The Applied Technology Council (ATC) – US -has entered into a contract with the Federal Emergency Management Agency (FEMA) –US- to develop a next generation of performance-based seismic design guidelines for buildings (project ATC-58). The work includes a building taxonomy and damage states for several structural and non-structural components.
Business Requirement (BR)	A BR is a statement of the functions needed in order to accomplish the business objectives. It is the highest level of requirement, developed through the dictation of policy and process by the business owner.
Business Rule (RU)	An RU is a statement that defines or constrains some aspect of the business. It is intended to assert business structure, or to control or influence the behaviour of the business. The RUs that concern the project are atomic in that they cannot be further decomposed and they are not process-dependent, so that they apply at all times. Business rules typically fall into one of five categories: terms, facts, derivations, assertions or action enablers.
Damage or Limit State	For a particular component, or the building as a whole, a range of damage conditions associated with unique consequences.
Floor Acceleration	At a floor level, the acceleration of the centre of mass relative to a fixed point in space.
Functional Requirement (FR)	An FR is a statement of an action or expectation of what the system will take or do. It is measured by concrete means like data values, decision making logic and algorithms.
GEM (Global Earthquake Model)	In the GEM project researchers from different countries are developing a physical earthquake risk estimation model of global use. In it a common terminology or taxonomy is critical to document variations in building design and construction practices around the world
In-Plane Behaviour	Behaviour that occurs in the direction parallel to the orientation of the element, which is typically a wall. The term is often used to describe failure, where for instance door and window openings in a wall may no longer have right angle corners.
Interstory Drift	The relative horizontal displacement of two adjacent floors in a building. Inter-story drift can also be expressed as a percentage of the story height separating the adjacent floors.
Non-functional Requirement (NR)	An NR is a low-level requirement that focuses on the specific characteristics that must be addressed in order to be acceptable as an end product. NRs have a focus on messaging, security, and system interaction.
Non-structural Components	In this work these are components that are a permanent part of the building and are not part of the structural system.
Out-of-Plane Behaviour	Behaviour that occurs in the direction perpendicular to the orientation of the structural element, which is typically a wall. The term is often used to describe failure, where for instance a wall may deform outwards or completely collapse into the adjacent street or valley.
Scenario	A scenario is a sequence of steps taken to complete a user requirement, similar to a use case.

Term	Definition
Structural Components	Building components that are part of the intended gravity, seismic, blast/impact or fire forces resisting system, or that provide measurable resistance to these forces.
Taxonomy	A hierarchical classification system
Unreinforced Masonry Wall	Clay brick or concrete or natural stone units bound together using lime or cement mortar to form o wall, without any reinforcing elements such as steel reinforcing bars.
Use Case	A use case is a description of a system's behaviour as it responds to a request that originates from outside of that system. The use case is made up of a set of possible sequences of interactions between systems and users in a particular environment and related to a particular goal. The use case should contain all system activities that have significance to the users. Use cases typically avoid technical jargon, preferring instead the language of the subject matter expert.
User Requirement (UR)	A UR is a statement of what users need to accomplish. It is a mid-level requirement describing specific operations for a user (e.g., a business user, system administrator, or the system itself). They are usually written in the user's language and define what the user expects from the end product.

EXECUTIVE SUMMARY

Rapid and accurate assessment of physical damage to constructed facilities is essential after disaster events (Kerle, 2011). This is especially true for assets that are significant for response and recovery efforts, such as buildings that constitute the physical backbone of modern society including public administration (e.g. ministries), public utilities (e.g. water, electricity) and emergency and security services (e.g. hospitals, police stations).

The first step to establish a basis for the development of the RECONASS system is this first deliverable of Work package 1. After the analysis of state of the art assessment tools, the collection of preliminary user requirements is necessary to understand the user needs which will be identified mainly through the completion of a questionnaire and by participating in a dedicated workshop. These will assist us in generating the final user requirements for the upcoming deliverable D1.3.

First, the state of the art was summarised conducting a literature review. Special emphasis was put on the determined shortfalls and misfits of the tools. The disaster events in Haiti 2010 and the region of L'Aquila/Italy 2009 which were caused by severe earthquakes and the Oklahoma City bombing of the Murrah Building 1995 have been analysed focussing on the lessons learnt related to assessment tools.

Based on that and on the input of the RECONASS partners and of experienced THW members, a questionnaire has been created to accomplish, specify and consolidate the user requirements.

In parallel, a user group was established to further elaborate and consolidate the requirements and to accompany the whole development process of the RECONASS system. Due to the scope of the RECONASS project, diverse users are expected to interact with the system. These are planners and operators of buildings and of the technical infrastructure, members of emergency and disaster response organisations, providers of damage maps, insurers and further stakeholders. To cope with the different requirements of these users, six groups of user types were defined.

The members of the user group were asked to complete the questionnaire and were invited to a workshop to further work on the user requirements. The first 19 answers were used to elaborate the preliminary user requirements and to prepare the user workshop that is described in deliverable 1.2.

Based on these steps, a first list of preliminary user requirements with 102 entries and a related classification system was created. The classification of the user requirements comprises the classification of the RECONASS sub-systems, the relevant user types, different functional and non-functional requirement types and the classification of the necessities (must, should, could, won't).

The work of this deliverable is the basis for the continuing work and will be evaluated and further developed with the members of the user group and the RECONASS partners. To this scope the next steps will be the user meeting, further extension of the user group and further dissemination of the questionnaire.

INTRODUCTION

This first deliverable of Work package 1 aims to establish a basis for the development of the RECONASS system. Preliminary user requirements are identified as a precondition to prepare the first end-user workshop. The results from this workshop then will be used to generate the final user requirements that will be summarised in deliverable 1.3.

At first, the state of the art is summarised conducting a literature review. Special emphasis is put on the determined shortfalls and misfits in the field of 1) Accurate positioning and secure communication, 2) Damage, Loss and Needs Assessment Methods for recovery and reconstruction planning and 3) Synergistic Damage Assessment with Air and Space borne Remote Sensing resulted from the state of the art analysis. These results are used to formulate requirements that will be included in the list of preliminary user requirements. Moreover, international projects and organisations such as the United Nations programme GDACS (Global Disaster Alert and Coordination System) or the German AURIS research project are listed to consider standards and best practises for the development of the RECONASS system.

Subsequently in chapter 2, the disaster events in Haiti 2010 and the region of L'Aquila/Italy 2009 and the Oklahoma City bombing of the Murrah Building 1995 are analysed. Special focus is put on the lessons learnt and on the effect of the used damage, loss and needs assessment tools.

In chapter 3, a questionnaire is created to accomplish, specify and consolidate the preliminary user requirements based on the previously obtained requirements and the input of the RECONASS partners and of experienced THW members. A user group is established with the relevant user types. This user group will join user workshops at the beginning, midterm and end of the RECONASS project and will support the development process by answering questions and questionnaires. This helps to elaborate and consolidate the requirements

Following these steps, a classification system for the user requirements is created. It includes the relevant user types, the RECONASS sub-systems, different functional and non-functional requirement types and the classification of the necessities (must, should, could, won't). This system is used for the first set of preliminary user requirements.

Based on the results of this deliverable D1.1 the end-user workshop will be organised. The end-user group and will be extended furthermore during the work period of the RECONASS project.

1. STATE OF THE ART-TECHNOLOGICAL BENCHMARKS

1.1. Introduction

The state of the art analysis comprises the different fields of research that are part of the RECONASS project and highlights the shortfalls and misfits in these research areas. It is divided into the sections 1) Accurate positioning and secure communication, 2) Damage, Loss and Needs Assessment Methods for recovery and reconstruction planning and 3) Synergistic Damage Assessment with Air and Space borne Remote Sensing. The analysis is one of the sources for the development needs and the preliminary user requirements. These requirements are summarised in each section.

1.2. Accurate Positioning and Secure Communication

Accurate and real-time position estimation of structural building elements like columns and beams and secure communication is necessary to estimate automatically, reliably and in near real time the structural condition of a monitored building and its damages. In reinforced concrete buildings, high signal attenuation and multipath propagation is a major obstacle to reach this goal. The state of the art and the requirements for this particular RECONASS research area will be covered in the following sections.

1.2.1. Local Positioning Systems (LPS)

Commercial Tracking and Positioning Systems

The following tables, namely Table 1 and Table 2, describe the recent widely used localization systems that are available on the market and the TU Dresden research prototypes respectively.)

Currently available wireless distance measurement solutions like e.g., Ubisense, MeshTrack, nanoLOC, Symeo LPR or ActiveBat (see Table 1) do not fulfil the RECONASS expected system requirements either in terms of non-line-of-sight distance measurements, accuracy or in terms of resilience in multipath environments. A combination of FMCW radar techniques with RF beam steering and/or a multi band RF front end will enable wireless, non-line-of-sight distance measurements within the RECONASS system specification. Furthermore the operation scenario which asks for distances measurements of fixed anchor nodes allows the implementation of new post processing algorithms to further increase the detection accuracy based on the overlay with pre-disaster measurements. A novel aspect of the RECONASS LPS is expected to be its integration into the building structure which will lead to completely new requirements to the antenna design.

This leads to the following necessary advancements to the state of the art:

The system is to be used within a building structure, usually made of reinforced concrete. High signal attenuation and multipath propagation is to be expected. Therefore TUD wants to research ways to retain the accuracy and coverage of a localization system within those complicated environments by different technical means:

- Use of directive antennas or antenna arrays for beam steering. This technique can help to attenuate multipath reflections, since the steered beam attenuates the unwanted signals, which arrive at the base station.
- Use of multiple frequency bands to increase robustness. This technique allows changing to other bands, if there the channel is impaired, e.g. by interference. Furthermore, measurements from multiple bands can be combined to increase the overall positioning accuracy.
- If system will be fixed within the structure, power management will be an issue to allow long operation times without maintenance. Therefore, concepts have to be researched to enhance battery life and lower power consumption (e.g. using wake-up receivers). Furthermore, antenna design is an issue for a system embedded in a structure.

Table 1: COTS Localization Systems

Name	Manufacturer	Technology	Range / m	Accuracy / m	Real-time capable?	CommChannel?	Base Stations/ Deployment	Primary Application	Cost
Ubisense	Ubisense	RF Pulse	160	4	yes	yes	several fixed	assets tracking in industry	~15kEUR for 5 modules
LPR-2D/GPS	Symeo	RF FMCW/GPS	400	<0.05	yes	no	several fixed	assets tracking in mining and industry	custom-made solutions, probably >1kEUR/module
nanoLOC	Nanotron	RF Pulse	200	13	no	yes	several ad-hoc		~5kEUR for 5 modules
"Indoor-Outdoor-Ortung"	Solcon Systemtechnik GmbH	RFID/LPS/ GPS	Not published	Not published	Not published	yes, WLAN	several fixed	tracking in hospitals, industry	custom-made solution
"Local Positioning System"	Sarissa	Ultrasound	4	<0.1	yes	no	single fixed	tools and assets tracking in industry	upon quote request
LPTS	iTrack	RF	n/a	n/a	n/a	n/a	several, min. 2, ad-hoc	person tracking, robotic tracking	upon quote request
IPCS	9Solutions	RF Bluetooth	50	n/a	yes	yes	several ad-hoc	tracking in hospitals	~3.3kEUR for 10 modules

Table 2: Research prototypes for LPS (TU Dresden)

Name	Status	Technology	Range / m	Accuracy / m	Real-time capable?	Comm. channel?	Base stations/ Deployment	Primary Application	Prototype Cost
E-Sponder time difference of arrival	under development	RF FMCW 2.4/5.8 GHz	300	1.50	yes	no	several ad-hoc	first responder tracking	~800EUR/module (base station or tag)
LommID reflector	done	RF FMCW 34 GHz	100 (only line-of-sight)	0.02	depending on no. of tags	possible, but not in current version	1 (measures only distances)	-	~1kEUR/base station, ~300EUR/tag
Lynceus reflector	under development	RF FMCW 2.4 GHz	500 (to be verified)	50 (to be verified)	depending on no. of tags	no	1 (on UAV)	tracking castaways	~5kEUR/base station, ~200EUR/tag
RECONASS system	planning	RF FMCW Multi-band, multi-antenna 2.4/5.8 GHz	several 10m? tbd.	1-2 3D (according to DoW), spec. tbd.	yes	yes? (maybe for maintenance) tbd.	fixed, embedded in the structure	Structural monitoring in buildings	to be investigated within RECONASS

- Implementation of innovative processing algorithms the get the most out of the raw data from the system. This includes data fusion algorithms such as particle filter.
- SotA commercial positioning systems (see table 1) are not designed for embedment inside the structure. A common application is assets tracking, which has different requirements than structural monitoring. Those systems usually rely on line-of-sight conditions. Accuracy and coverage range are contradictory. Real-time capability depends on the number of users in most systems. In RECONASS, a system will be developed which will mitigate those shortcomings. Besides the FMCW approach, which has been used for several demonstrators for research projects at TUD, also other concepts like RF pulse-based or ultrasound solutions will be investigated.

1.2.2. Communications between Sensors and the Gateway

Introduction

Smart sensor applications continue to grow in the modern world in all fields of industrial or commercial technological sectors like for example in building construction, civilian infrastructure, shipboard, industrial automation, smart home applications, transportation. Cognition and environmental awareness is a key concept for the operation of these types of applications and thus the need for specialized sensors, and sensor networks that provide useful readings of the surrounding environment like for example temperature, humidity, pressure, acceleration, is ever growing.

With the rapid growth of narrowband and broadband wireless technologies even in civilian or ISM bands and also with the rapid increase for the need of sensor networks in inaccessible locations wired sensor networks are slowly becoming “a thing of the past” while wireless sensor networks have become a common trend.

These wireless sensor networks (WSNs) in most cases operate without the support of a permanent power supply relying solely to a dedicated battery for their operation. This power constraint renders power efficiency a critical consideration while designing such systems to ensure an extended life cycle of the WSN. Wireless technologies have emerged to support such networks with a design approach centred on power efficiency and the need to support a large mesh wireless network with short range wireless transmissions. While most wireless implementations dedicated for such purposes are based upon the specifications offered by major standardization bodies such as IEEE 802.15.4, IEEE 802.15.6, IETF and ISO and in parallel by industrial alliances such as Zig-Bee, Wireless HART, MiWi and IPSO during the latest years, special consideration has been given to the MAC’s specifications. For the latter recent research activities aim at the design for ultra-low power wireless applications. Such specifications include PicoRadio, SyncWUF, WiseMAC and X-MAC. The last two specifications are offered with even lower power limitations than the 802.15.4 based ones.

Wireless sensor networks (WSN) and gateways

Wireless sensor nodes in a “low power” wireless sensor network are usually low power embedded devices powered by low power microcontrollers with limited computational resources and networking capabilities. In many scenarios it is difficult to retrieve useful data directly from all sensors (especially in scenarios where heterogeneous wireless sensors are used) and thus a sensor data aggregation point is required. This sensor data aggregation point is often referred to as a sensor gateway or a sensor relay.

This sensor gateway is a common endpoint for wireless sensors and it can be used as a

i. Data concentrator point for logging purposes
ii. A sensor control point to forward operational parameters to wireless sensors
iii. A relay point for the uplink of sensor data with a different wired or wireless uplink technology (such as Ethernet, Wi-Fi, WiMAX, UMTS etc.)
iv. A relay point between two or more separate wireless sensor networks that utilize different wireless access schemes or between a sensor network and a similar redundant sensor network for failover purposes.

The proper design of the sensor gateway in a distributed wireless sensor network is crucial to ensure the best possible performance and reliability of the sensor network.

Figure 1 illustrates an 802.15.4 based wireless sensor network supported by a sensor gateway that provides a

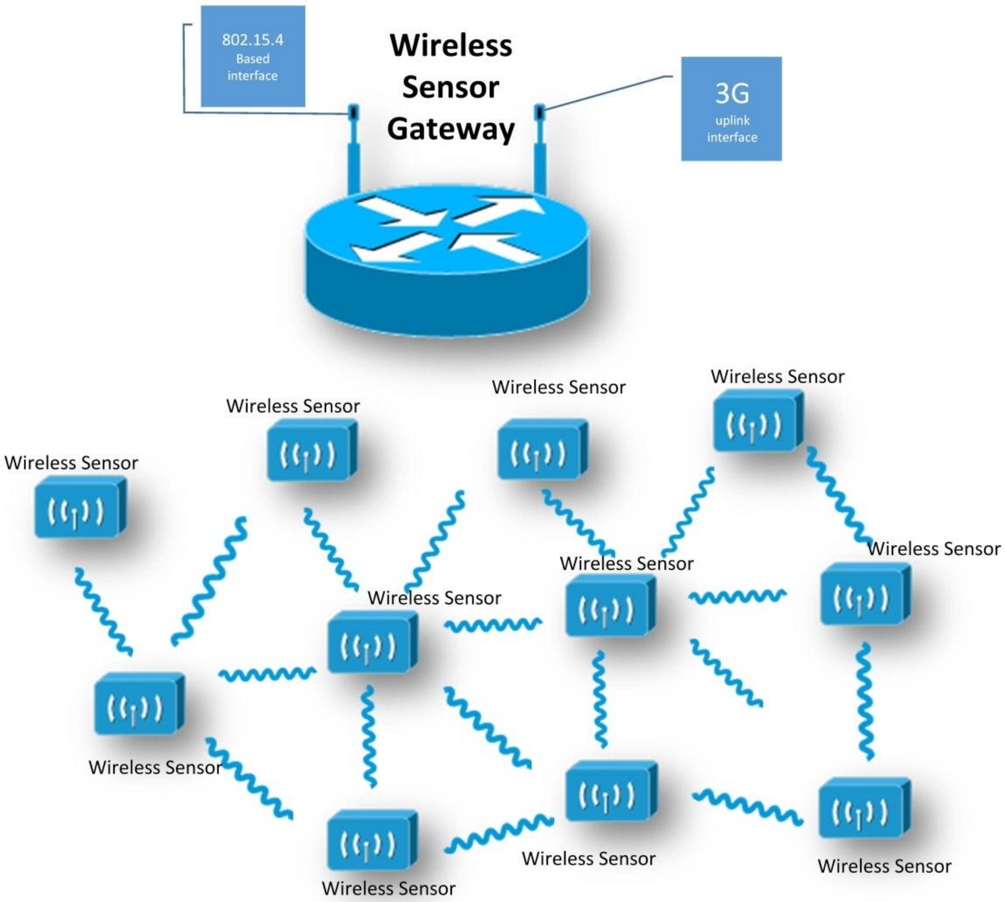


Figure 1: A wireless sensor network with gateway for 3G uplink

The WSN Gateway is characterized as one of the most important components of a WSN by efficiently controlling, aggregating and providing the communication routes for the overall sensing activity of such a network. The gateway collects the sensing information in dedicated databases and makes this information available usually via a wireless network. In that sense, it provides the interface between the sensor nodes and the network infrastructure. The design and the development of a typical wireless sensor network gateway include utilizing a processor and several microcontroller modules. For handling the operational functionalities further features of the mainboard include the different configurations of flash memories such as SDRAM, SD/MMC, DataFlash, etc. In addition, the embedded operating system that could be used, such as Linux, or Windows-based, affects and depends on the level of further development and customization that is required to be achieved and the features that are expected to be supported such as multitasking, shared libraries and virtual memory. Depending also on the operating system to be embedded there are a variety of services (http, ssh, etc.), programming environments (C, C++, Java, PHP, Python, Perl, etc.) and database systems (MySQL, Postgre, etc.) that are supported.

Modern sensor gateways

Since the technology to support wireless sensor networks has already been around for more than a decade, at this point there are numerous vendors manufacturing wireless sensors and wireless sensor gateways. Most of these devices are based upon or utilize variants of the IEEE 802.15.4 specification (from 802.15.4-2003 to 802.15.4d-2009 and other variations) for wireless sensor network part while in some cases proprietary vendor specific low power wireless protocols are used.

Some of the well-known manufacturers of wireless microcontroller boards based upon the IEEE 802.15.4 specification are ATMEL (1), Digi International (2), California Eastern laboratories (3), Dresden Electronic (4)ith their own implementation of the specification (mainly Zig-Bee) and in many cases customization software tools for the MAC layer.

While there are numerous manufacturers of wireless 802.15.4 based microcontroller board and sensor manufacturers offering a great diversity of products, in the case of wireless gateways for wireless sensors most manufacturers offer gateway solutions to support their own proprietary sensor network solution for aggregation logging data formatting or backbone uplink and node authentication purposes.

Some noteworthy examples of such wireless sensor gateway solutions are the following:

a) The NI 9792 Programmable Wireless sensor gateway (5) by National Instruments, the purpose of this gateway is to aggregate messages from wireless sensor measurement nodes, to provide message buffering and wireless node authentication and furthermore to bridge the 802.15.4 based sensor network with an 802.3 based Ethernet network.

Figure 2: National instruments sensor gateway (National Instruments 2014)

b) MeshLium extreme by Libelium (6) is one of the most versatile wireless sensors gateway solutions with the ability to manage sensors and aggregate wireless sensor data from different wireless sensor networks that utilize heterogeneous wireless transmission access schemes (not just Zig-Bee but also Wi-Fi, GPRS etc.) and plus to provide a data backbone interconnection capability to these sensor networks via more than one access technology (802.3, 802.11, 3G, etc.). However despite being so versatile the gateway is still limited to the fact that it can support wireless sensor nodes provided by the same manufacturer.

Figure 3: *Sensor Gateway by Libelium (Libelium 2014)*

c) Lord Microstrain (7) provides reliable industrial wireless sensors and wireless sensor gateways as well as ruggedized wireless sensor gateways (MIL-STD-810 Standard compliance) mainly for sensor data aggregation sensor control and remote management. This company uses its in house developed proprietary wireless sensor communication protocol LXRS which is based upon the 802.15.4 specification with extensions that provide lossless transmission extended range and wireless sensor node synchronization.

Figure 4*: Sensor Gateway by Lord Microstrain (Microstrain 2014)*

d) Siemens (8) utilizes the WirelessHART based wireless sensor communication protocol (instead of Zig-Bee) for its industrial sensorial network solutions. In addition utilizes a series of wireless sensor gateways (like the IE/WSN-PA LINK), which is merely for providing an interconnection of the lower level WirelessHART devices to a higher level network (TCP/IP) network plus offering network configuration node management for WirelessHART sensor devices through a web interface

Figure 5*: Sensor Gateway by Siemens (Siemens 2014)*

Despite the fact that a wide variety of gateways solutions in the field of wireless sensor networks are available at this moment from numerous different vendors, it is clear that a common framework of communication between different market solutions of wireless sensor networks is missing since vendors prefer to use their own proprietary communication schemes and to support their own sensor products by their gateways.

In many modern wireless sensor applications in which more complex communication architecture scenarios (i.e. interoperability among heterogeneous networks, different sensor technologies integration, need for power efficiency and adapting protocol parameters, etc.) are enabled a single vendor solution or a single wireless access technology is not sufficient to support all the different needs for customization and optimisation. In these cases, vendor specific wireless sensor gateways are incapable of supporting the requirements of such systems and thus custom build sensor gateway solutions are required.

A simple literature search retrieves various different research projects on studying wireless sensor networks and gateways attempting to address the problem of interoperability and cooperation between heterogeneous or vendor specific wireless sensor networks by using custom sensor gateways. Some noteworthy examples are presented below:

- Philip Suba, Christian Prehofer, Jilles van Gurp from the Nokia Research Centre in their related work “Towards and Common Sensor Network API” (1) have made a serious effort to bridge two diametrically different types of wireless sensor networks by building a separate abstraction layer and a web services enabled communication API in a custom gateway with security fault tolerance and interoperability. However many vendor specific functions could not be implemented on the common gateway and thus the end user would not be able to operate the sensor networks in their full capabilities.

- In their related work “A modular wireless sensor gateway design” Lili Wu, Jane Riihijarvi and Petri Mahonen from the research department of wireless networks at Aachen University, (2) is exploiting the concept of creating a modular wireless sensor network gateway design. The aim here is to create a common API and a description language in XML to enable the interconnection of heterogeneous wireless sensor networks that utilize different protocol stacks to wide area networks and plus the ability to describe new networks that can be added to the system.
- A routing protocol is presented in the related document “Coverage and Connectivity Preserving Routing Protocol for heterogeneous wireless sensor networks” by Ben Alla, S. from the Mathematics and Computer Science Department at Hassan 1 University (3) that allows coverage and connectivity preservation in order to ensure a predefined acceptable quality of service in the communication between heterogeneous wireless sensor networks, while also ensuring power efficiency by selecting proper nodes and gateways for the optimal route of data.
- The concept of wireless sensor networks with multiple gateways is considered and the scaling capacity of such scenarios with multiple gateway nodes is examined in the related work by Panlong Yang from the Institute of Communications and Engineering at P.L.A University “Characterizing the Scaling Capacity of Multiple Gateway Access in Wireless Sensor Networks” (4)

1.3. Introduction of the RECONASS Wireless Sensor Gateway

The RECONNASS project will provide all the tools and software required to implement a system that will support constructed facilities by providing a near real time continuously updated assessment of their structural condition after a possible disaster in order to provide the necessary information for fast recovery planning by the responsible organisation.

For the purposes of achieving this goal a large mesh multi-hop wireless sensor network must be deployed with various sensors being embedded in a number of pre-defined points during the construction process of the target facility.

Data from acceleration, strain and temperature sensors as well as accurate GPS positioning information must be properly collected, stored, formatted and forwarded to a special assessment software responsible for the detailed reporting of the current structural integrity of the target facilities. This data will have to be obtained by various sensor networks and to be transmitted by utilizing different backbone uplink technologies such as:

- GSM
- UMTS
- Wi-Fi (802.11a/b/g/n)
- WiMax (802.16d or 802.16e)
- Wire line

In addition the wireless sensor nodes that operate in these sensor networks will have to be ultra-efficient in terms of power consumption since the sensor network will be embedded or attached in the target facility starting from the construction process and thus wireless sensor nodes will have to operate for the years to come with a limited power supply.

To support such a sensor network a vendor specific gateway solution is not sufficient since multiple wireless sensor networks will have to coexist and interoperate, data will have to be transmitted over heterogeneous networks, logic is needed to be applied for data control and operations and adapting protocol parameters will be optimizing the data traffic at runtime. For these purposes and for supporting the data aggregation, storage, message formatting, and validation interworked by these multiple data sources of multiple different wireless sensor networks a custom specialized sensor gateway must be designed and implemented.

To design such a sensor network there are many challenges to overcome and considerations to take in mind. Some of the most important considerations – challenges that should be taken into account during the realization of the gateway are the following.

i. Interoperability, the gateway must be able to bridge different types of sensor networks and convert different types of input sensor data into a usable format that can be easily used by the assessment software.
ii. Energy efficiency of wireless sensor networks should be considered by taking into account the power availability of sensor networks in the data acquisition process.
iii. Fault tolerance features should be considered that characterize failing sensors and possibly isolate with the assistance of a dedicated routing protocol that provides the ability to reroute data paths from failing sensor networks.
iv. Interconnection capabilities between heterogeneous networks with different uplink technologies should be realized and thus the sensor gateway should incorporate various different wireless access technologies supported by their corresponding wireless interfaces.
v. Security and wireless sensor network authorization and authentication should be considered to ensure the validity of data and the proper validation of a sensor network's presence in the system.
vi. Bandwidth limitations of wireless or wired technologies utilized by the sensor network should be considered so that it is ensured that the available bandwidth is able to support all data sources reliably

By taking into account the current offering of vendors in the market of sensor gateways and the recent research in designing "multi-purpose" sensor gateways the design and implementation of such a gateway is challenging and will provide a significant level of innovation in the field of gateways for wireless sensor networks.

1.3.1. Necessary Improvements in the Field of Accurate Positioning and Secure Communication - Conclusions

In the field of accurate positioning and secure communication, the challenges and necessary improvements beyond the state of the art were indicated in the respective sections above. To summarise this in the field of local positioning systems, a high positioning accuracy and coverage must be reached within a building structure made of reinforced concrete. Additionally the system must be embedded in the building structure taking into account power consumption, maintenance and reliability.

The communication between sensors and gateways must be further developed in the field of interoperability between different sensor network types and energy efficiency. Fault tolerance, data security and bandwidth must be enhanced to reach a sufficient reliability and security level.

Following the preceding information, necessary improvements for the RECONASS project are (see Table 3):

Table 3: Requirements in the field of accurate positioning and secure communication

Nr.	Requirement	Specific domain involved
1.1	Accuracy of non line of sight measurement	Positioning and distance measurement
1.2	Resilience in multi-path environments	Positioning and distance measurement and secure communication
1.3	Enhanced accuracy by comparison of pre- and post event measurements	Positioning and distance measurement
1.4	Integration into the building structure and antenna design	Positioning and distance measurement and secure communication
1.5	Low power consumption to enhance battery life	Positioning and distance measurement and secure communication
1.6	Enhanced range in reinforced concrete buildings	Positioning and distance measurement secure communication
1.7	Common framework of communication for sensor networks	Secure communication
1.8	Communication gateway must be interoperable to bridge between different types of sensor networks	Secure communication
1.9	Fault tolerance: if sensor nodes fail, the communication system must reroute the data paths	Secure communication
1.10	Interoperability: the gateway should be capable to operate different wireless access technologies	Secure communication
1.11	Measurement data must be transported secure and not be manipulated.	Secure communication
1.12	Sensor data acquirement and data transmission must be fast enough to allow near real time damage assessment	Positioning and distance measurement secure communication

1.4. Damage, Loss and Needs Assessment Methods for recovery and reconstruction planning

To ensure fast end effective response and recovery activities, the planning of these measures must be prepared prior to the event and must start early after it on the basis of acquiring reliable and comprehensive damage and loss data from various sources. The state of the art and the requirements for this research area of primary importance within RECONASS will be covered in the following sections.

1.4.1. Post earthquake response and recovery

GDACS

The Global Disaster Alert and Coordination System GDACS (www.gdacs.org) is a cooperation framework under the United Nations umbrella. It includes disaster managers and disaster information systems worldwide and aims at filling the information and coordination gap in the first phase after major disasters.

GDACS provides alerts and impact estimations after major disasters (see Figure 6) through a multi-hazard disaster impact assessment service managed by the European Commission Joint Research Centre (http://globesec.jrc.ec.europa.eu/). To this end, JRC establishes scientific partnerships with global hazard monitoring organisations. Flood disasters are provided by the Dartmouth Flood Observatory (http://floodobservatory.colorado.edu/). Relevant data is integrated automatically into GDACS alerts and impact estimations.

To support disaster managers worldwide, GDACS provides the real-time coordination platform "VirtualOSOCC" (http://vosocc.gdacs.org). GDACS coordinates the creation and dissemination of disaster maps and satellite images. This service is facilitated by the UN Institute for Training and Research (UNITAR) Operational Satellite Applications Programme (UNOSAT). Relevant maps are integrated automatically in VirtualOSOCC disaster discussions.

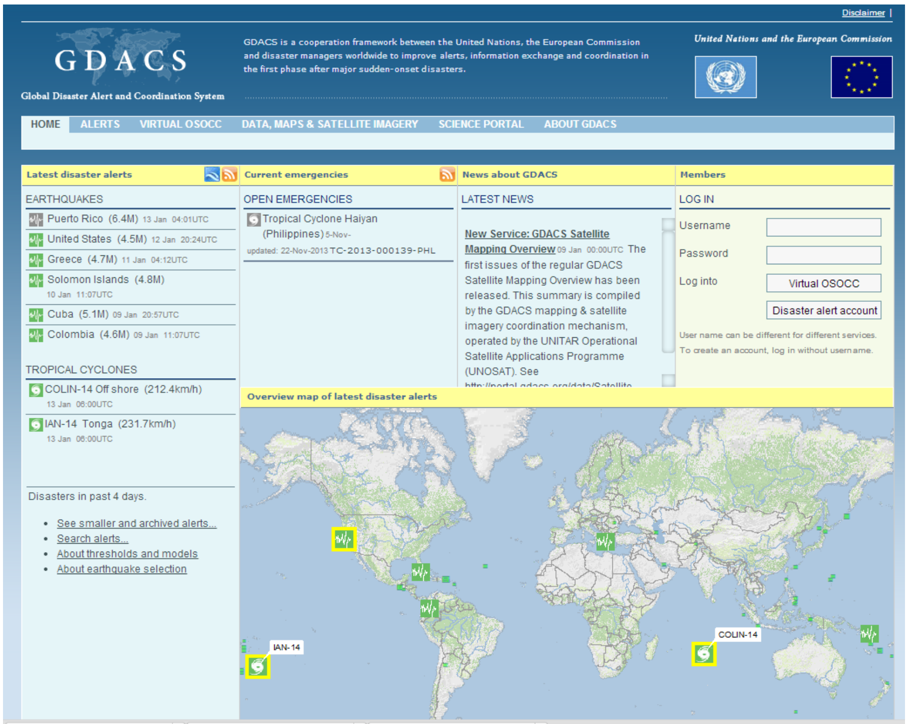


Figure 6: *GDACS - Global Disaster Alert and Coordination System homepage*

Many governments and disaster response organisations such as THW rely on GDACS alerts and automatic impact estimations to prepare and coordinate their international assistance. Some 14,000 disaster managers from governmental and non-governmental organisations have subscribed to the VirtualOSOCC and use the tool for information exchange and coordination in the first disaster phase. Many governments and organisations have formalised the use of GDACS tools and services in their national disaster response plans, in particular its automatic alerts and impact estimations and the VirtualOSOCC.

GDACS information is openly accessible through the GDACS platform interfaces. It can be directly integrated into other web portals or websites through RSS feeds or other standard formats.

THW takes the GDACS impact estimations into consideration when it decides about sending its international teams. More detailed damage maps are shared via GDACS when available. The member of the user group ZKI/DLR (Center of Satellite Based Crisis Information (ZKI) at German Aerospace Center, Germany) delivers such maps via GDACS.

GDACS works as a data exchange provider on an international level. RECONASS, which collects data on a local level, aims in efficient collaboration and data exchange with such systems utilising an open platform that is expected to be developed to interwork with such systems. The interoperability between GDACS and RECONASS is a primary user requirement that can be achieved by RECONASS interfaces according to the existing national standards. Additionally, GDACS provides first damage and loss assessments, but the timely collection of reliable and accurate data from the disaster prone area must still be improved. Additionally, the integration of the collected data into the GDACS data set must be realized, because actually it takes more than three days to review and publish the locally collected data to the onsite teams.

COBACORE project

COBACORE stands for Community-Based Comprehensive Recovery and is a collaborative research project funded by the European Commission involving Dutch, UK, German, Irish, Spanish and Slovenian partners under the FP7 framework. The project started on April 1st, 2013 with duration of 36 months. COBACORE seeks to close the collaboration gaps between stakeholders involved in post-crisis recovery and aims to improve the matching of needs with capacities, through building upon the community as an important source of information and capabilities. The COBACORE suite of tools, which are designed to complement existing practices and tools, shall support common needs assessments efforts, damage recovery needs, economic needs, health and social needs, and other critical humanitarian needs. The COBACORE assets shall stimulate community-wide involvement in information gathering, sense-making, and needs assessment practices. (5)

The project addresses two main challenges: 1) the adoption of a comprehensive approach to needs assessment and recovery planning, and 2) the development of community building methods in disaster recovery. Main focus of the project is on communication and on education rather than on sensor based damage and needs assessment. But it is necessary to follow the results of the project because information exchange is crucial for the post disaster needs assessment.

IASC Operational Guidance for Coordinated Assessments in Humanitarian Crises

Experience has shown that coordinating needs assessments not only brings significant benefits but can also help save more lives and restore more people's livelihoods. Bearing in mind this valuable lesson, the Inter-Agency Standing Committee (IASC) established the Needs Assessment Task Force (NATF) in March 2009 to improve coordinated assessment processes and strengthen the identification of strategic humanitarian priorities in complex emergencies and natural disasters (6)

Along with emergency preparedness, the timeliness and quality of assessments help determine an effective humanitarian response. The credibility and accuracy of assessment results are the basis for needs-based planning and can have long-lasting effects on everything from the quality of interagency coordination, to donor funding levels and relationships with national governments, local nongovernmental organisations (NGOs) and disaster-affected populations.

The NATF developed an Operational Guidance for Coordinated Assessments in Humanitarian Crises to help realize the goal of better quality and more timely assessments through coordinated processes. It was not developed to fill a lack of assessment guidelines and tools, but rather to provide guidance for those seeking to make informed decisions on the coordination of assessments (harmonized or joint). The Operational Guidance was developed primarily on the basis of experiences gained during the early phases of large-scale quick-onset natural disasters, but it is also applicable to other types of crises. It provides guidance to coordinate assessments as well as tools.

The NATF developed this Operational Guidance through a collaborative and consultative process with United Nations agencies, other international organisations, NGOs and donors at the global, regional and national levels. The Guidance was developed within the accountability framework of the humanitarian reform, and is fully in line with the coordination structures introduced by the cluster approach (6).

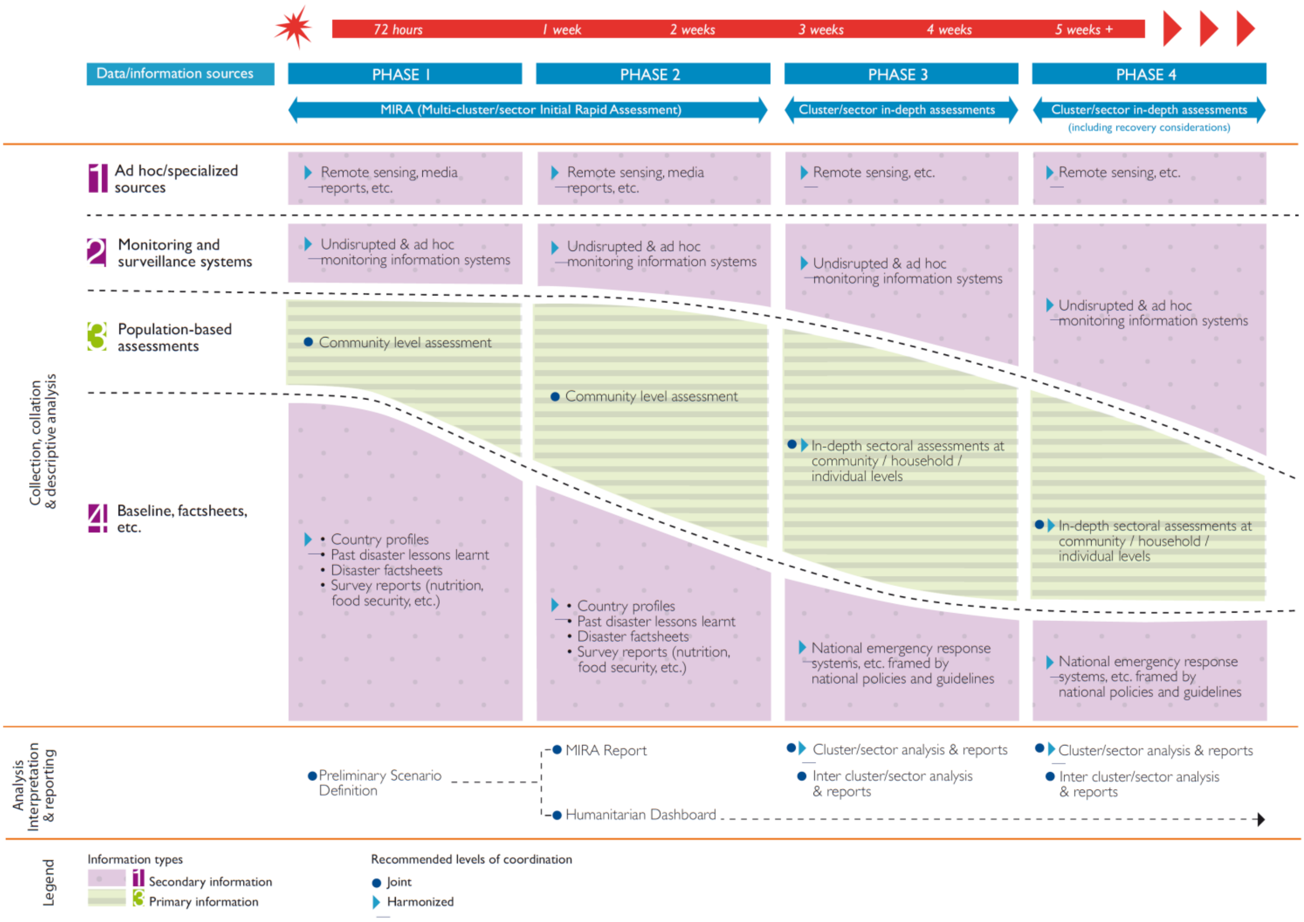


Figure 7: IASC Operational guidance document, timeline of data source usage (IASC 2012).

The guidelines document concentrates on the coordination aspects and does not intend to provide technical solutions. But it stresses the need of a coordinated approach and information exchange between different stakeholders after an emergency or a disaster. It is based on the experiences gained during large-scale quick-onset natural disasters.

PAGER / ShakeMap

PAGER (Prompt Assessment of Global Earthquakes for Response) is a system that provides fatality and economic loss impact estimates following significant earthquakes (7).It was developed by the U.S. Geological Survey (USGS) to improve the accuracy of assessment of potential earthquake damages. PAGERs estimation results are generally available within 30 minutes after an earthquake, they contain „Alert message, as well as supplementary information, including comments describing the dominant types of vulnerable buildings in the region, exposure and any fatality reports from previous nearby earthquakes, and a summary of regionally specific information concerning the potential for secondary hazards, such as earthquake-induced landslides, tsunami, and liquefaction. “

PAGER will send update messages with more accurate maps and refined estimates as more data becomes available. Typical PAGER alert recipients are emergency responders, government and aid agencies.

DESTRIERO

DESTRIERO is a GIS based operational-level decision support and needs assessment tool for disaster managers. Its focus is on improving the data collection and information sharing between relief organisations and their information systems for coordinated damage and needs assessment and reconstruction and recovery operations. It aims at supporting the continuous damage and contamination assessment, monitoring and updating as well as visualizing the common operational picture, and therefore incorporates satellite and aerial imagery and field data collected with mobile apps (8). The DESTRIERO system is currently under development within the EU FP7 framework.

Istanbul Earthquake Rapid Response System

The Istanbul Earthquake Rapid Response System is an earthquake alerting system based on about 100 sensors and two data processing centres. It aims at providing real time estimations of earthquake damages using „most recently developed methodologies and up-to-date structural and demographic inventories of Istanbul city." (9).In a first step, ground motion estimations are based on detections from the systems sensors. In a second step, the ground motion estimations will be updated as more earthquake parameters become available. Third and final step is the estimation of building damages and casualties based on the ground motion parameters.

GEOCAN

GEOCAN is a web-based tool enabling a large team of experienced people to share the task of building-by-building assessment over a large damaged area, so that an overall assessment can be produced very rapidly („crowd-sourcing„)."After the 2010 Haiti earthquake, the GEOCAN team of more than 600 people was assembled by EERI within a few days of the earthquake, and produced a first damage map of the urban area of Port-au-Prince within a week of the occurrence of the event" (10).

GEOCAN allows creating an approximate assessment of building damages after an earthquake by conducting a building-by-building assessment over a large damaged area. The assessment result is limited to the top-down view from aerial imagery and therefore has a certain level of wrongly assigned damage levels, as comparisons with field assessments show. GEOCAN has been used after the Haiti (2010) and Christchurch (2011) earthquakes

1.4.2. Damage simulation and assessment

VEBE damage assessment tool

The VEBE model (11) is made for simulations of attacks with military conventional weapons and improvised explosive devices against urban areas, as well as major civil disasters like blasts and gas explosions. It describes how pressure and blast debris act upon buildings (incl. shelters), humans and underground supply systems, how fire is initiated and spread inside and between buildings and finally how the damaged buildings affect humans and shelters.

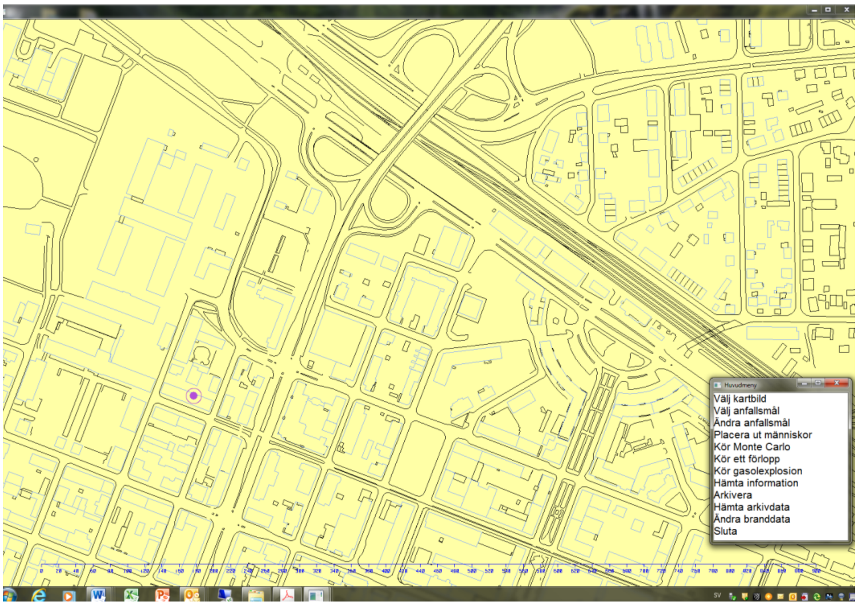


Figure 8: VEBE image from the computer screen showing a part of a city with point of explosion marked in a building to the left.

The area of interest is created by input of a digitized map showing buildings and streets (see Figure 8). Data for each building has to be input in terms of type of building and building height (number of stories). For the time being there are 21 different types of buildings that can be used (see Table 4).

Through Monte Carlo Sampling possible scenarios are simulated based on the pre-defined behaviour and assigned statistic properties.

Table 4: Different types of buildings presently available for the VEBE computer code

Building frame type	Type and typical structural features
R/C cast In-situ	B1TN: Exterior 0.2 m R/C load bearing walls
	B2LN: Load bearing R/C columns. Exterior non load bearing in-fill stud walls with steel panels
	B2MN: Load bearing R/C columns. Exterior non load bearing in-fill stud walls with brick veneer masonry
	B3MN: Load bearing R/C lateral walls. Longitudinal non load bearing in-fill exterior walls – gable
	B3MN: Load bearing R/C lateral walls. Longitudinal non load bearing exterior in-fill stud walls with brick masonry – long side
	B4TN: Monolithic R/C building with 0.15 m load bearing walls in both directions
R/C Pre-cast	P1MH: Exterior 0.25 m light weight concrete elements, 6 m span (warehouse or industry)
	P1TH: Exterior 0.3 m sandwich (concrete) elements, 4 m span (warehouse or industry)
	P1TN / P2TN: Exterior and interior concrete elements.
Steel frame	S1LH: Exterior walls with corrugated steel sheet on steel girders, 6 m span (warehouse or industry)
	S1LN: Load bearing columns with non load bearing infill exterior walls with steel girders and exterior steel panels
	S1MN: Load bearing columns with non load bearing brick masonry in-fill exterior walls
	S1TH: Exterior walls with two layers of 0.12 m brick masonry and intermediate insulation (warehouse or industry)
Masonry	M1LS: Exterior walls with 0.25 m light weight concrete
	M1TN: Exterior load bearing 0.25 m brick wall masonry
	M2TN: Exterior load bearing 0.38 m brick wall masonry
Wood	T1MN: Massive timber walls structure
	T2LH: Column beam structure with exterior wood panel covering on wooden girders (6 m span) (warehouse or industry)
	T3LH: Exterior wood panel covering on wooden girders (warehouse or industry)
	T3LN: Exterior wood panel covering on wooden girders
	T3MS: Exterior load bearing wood stud walls with exterior 0.12 m brick masonry

After calculation with one single round the consequences of an explosion, which can occur outdoors or indoors, are shown graphically on the screen by depicting different damage zones inside and outside the buildings (See Figure 9). There are four different damage zones inside of buildings ranging from severe to light damage, and three different outside the buildings, two concerning debris from on the ground and one concerning damaged windows (see Table 5).

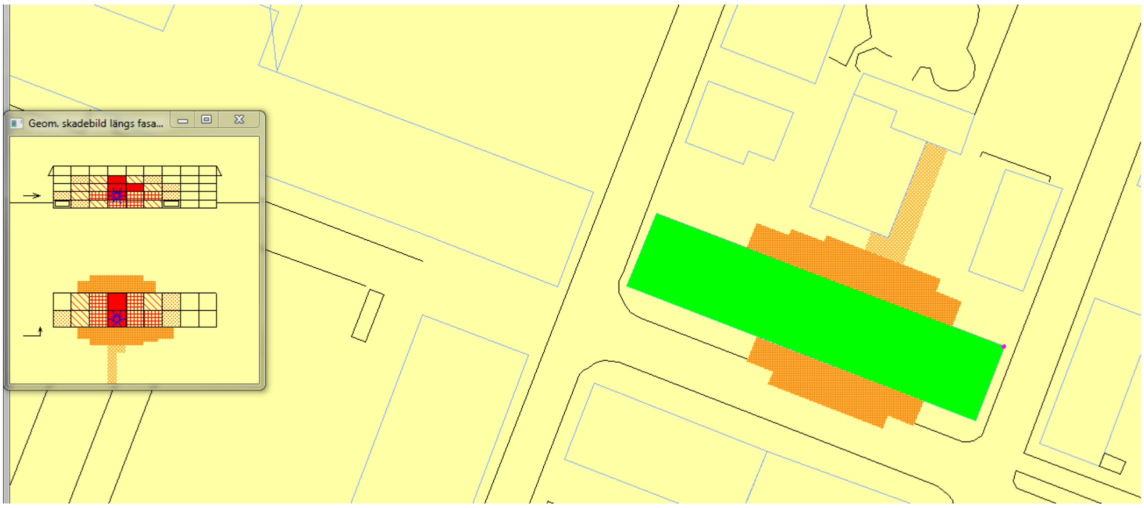


Figure 9: An example of output from the VEBE code where a high explosive charge has been detonated on the first floor of a building type M1TN. To the right it is shown different zones outside the building where debris is falling (dark orange) or thrown (light orange). The small figure to the left shows the building divided into construction units (volumes divided by load-bearing walls) with different damage zones inside the building (solid red – floor collapse zone, red grid – wall collapse zone, red hatched – crack zone and red dot pattern - shake zone).

Table 5: Different damage zones calculated by VEBE.

Zone	**Characteristics**
Floor collapse zone	Indoor damage zone with all floors collapsed and only empty space left
Wall collapse zone	Indoor damage zone where floors are present but at least one supporting wall of involved construction unit has collapsed
Crack zone	Indoor damager zone – zone with major cracks in load bearing walls
Shale zone	Indoor damage zone – minor cracks in load bearing structures but non-structural components may be heavily damaged
Debris fall zone	Outdoor damage zone - pieces of building material have tumbled down to the ground
Debris throw zone	Outdoor damage zone – zone with debris hurled away from the building
Window breaking zone	Outdoor damage zone – an area within which at least 50 % of the windows are broken

The model has previously been used for studies of damage prevention, rescue activities, training of rescue personnel and for planning within central and local authorities. It will be used to evaluate the RECONASS damage assessment modules, especially the modules to assess non-structural damages.

Currently there are no plans for development of the VEBE model as in the current design is focused on load bearing (“structural”) walls. However, there are already a couple of non load bearing (”non-structural”) walls namely in-fill stud walls with sheet steel panels, in-fill stud walls with brick masonry and in-fill plain brick masonry. Another “non-structural” component considered in VEBE is windows. However the VEBE model has presently only a very simple glass window damage sub module without possibilities to alter the structure or size of the window. The code shows an envelope of circles around different explosion points depicting the limit to where 50 % of the windows are expected to break.

HAZUS

Hazus is a nationally applicable standardized methodology that contains models for estimating potential losses from earthquakes, floods, and hurricanes. Hazus uses Geographic Information Systems (GIS) technology to estimate physical, economic, and social impacts of disasters. It graphically illustrates the limits of identified high-risk locations due to earthquake, hurricane, and floods. Users can then visualize the spatial relationships between populations and other more permanently fixed geographic assets or resources for the specific hazard being modelled. This is considered to be a crucial function in the pre-disaster planning process. (http://www.fema.gov/hazus)

Hazus is used for mitigation and recovery as well as preparedness and response. Government planners, GIS specialists, and emergency managers use Hazus to determine losses and the most beneficial mitigation approaches to take to minimize them. Hazus can be used in the assessment step in the mitigation planning process, which is the foundation for a community's long-term strategy to reduce disaster losses and break the cycle of disaster damage, reconstruction, and repeated damage. Being ready will aid in recovery after a natural disaster.

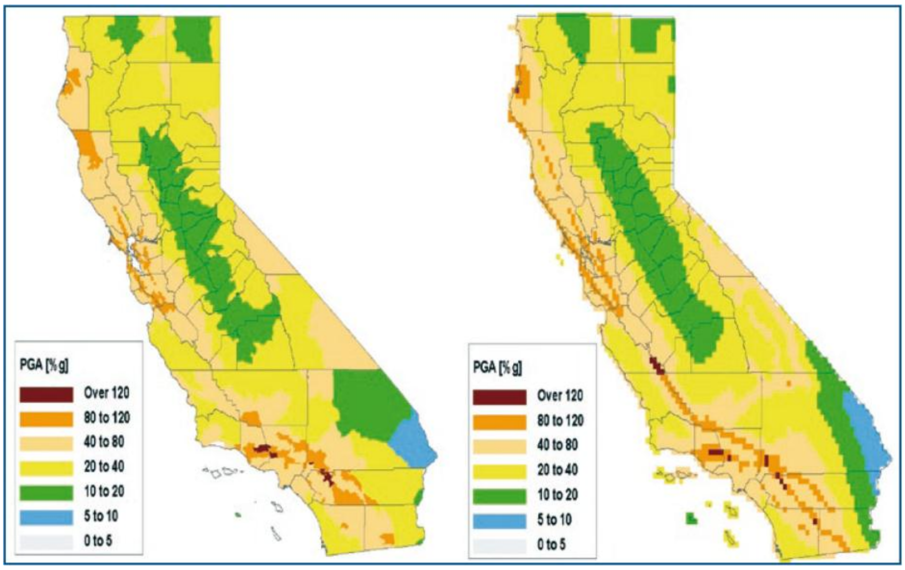


Figure 10*: HAZUS output example: Comparison of HAZUS-MH Seismic Hazard Map for PGA in % g (left) and a USGS 2002 Hazard Map (right) for 1,000-year Return Period Ground Motion for a Type B/C Soil* (12)

As the number of Hazus users continues to increase, so do the types of uses. Increasingly, Hazus is being used by states and communities in support of risk assessments perform economic loss scenarios for certain natural hazards and rapid needs assessments during hurricane response. Other communities are using Hazus to increase hazard awareness. Successful uses of Hazus are profiled under Mitigation and Recovery and Preparedness and Response. Emergency managers have also found these map templates helpful to support rapid impact assessment and disaster response.

The main precondition for proper damage and loss estimations is a detailed and up-to-date inventory database including building stock data, demographics, damage functions, data about lifelines and transportation. The Hazus methodology and data, originally created for the USA, must be transformed and adapted to the conditions in a specific area and will only be functional there. Such a system must be established long before a disaster strikes.

If the RECONASS system will be implemented in an area where a local loss estimation system is already in use, interoperability between these local systems must be assured using standardized interfaces.

AURIS Project

THW is partner in an ongoing German research project including the instrumentation of buildings for fast damage assessment, supported by the German Federal Ministry of Education and Research. The project duration is from June 2011 to May 2015 and partners involved are the Ed. Züblin AG (construction industry), Emergent Actio KG (a company dealing with market research), the research institutes Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institut, EM, Freiburg University - Institute for German and International Civil Procedure Law, Freiburg University - Institute of Microsystems Engineering, IMTEK and Karlsruhe Institute of Technology - Institute of Concrete Structures and Building Materials, IMB and the security service provider Securiton GmbH.

The aim of this project is to develop and conduct a long-term trial of an innovative building/structure safety management system intended to provide protection for people in critical infrastructure (13). This safety management system consists essentially of a measuring system to monitor the structure of the building and assess the actual condition of the building during its entire service life as well as during exceptional load impacts, e.g. during an explosion, accident or earthquake. Computer analysis of the data automatically collected by the system is conducted to establish the remaining structural capacity of the building; this data will provide information to safety and rescue teams about the actual condition on-site and the structural stability of the building. In addition, owners and operators of buildings or structures can obtain updated information on the condition of their buildings during operation.

Data can be collected with energy self-sufficient radio sensors. Existing detection systems can also be integrated into the system. The long-term trial of the measuring system will be conducted in a part of an exemplary building such as a train station, an airport, or an office building.

The research project is still under progress. At moment, there are no commercial outcomes of this project. Integration of the damage data into existing damage maps on city level is not planned. The further project results will be monitored.

WAPMERR / QLARM:

QLARM is a tool for real-time loss estimates after earthquakes. Within minutes to hours, it provides estimated numbers of fatalities and injured as well as average damage to buildings. QLARM uses the earthquake origin time, location, depth and magnitude and data on settlement population and building fragility for its calculations. Alert messages are sent as email including a map showing the average loss in the affected settlements and a list of these settlements with differentiated loss estimates within each. QLARM was developed in Switzerland by the World Agency of Planetary Monitoring And Earthquake Risk Reduction (14).

RADIUS

The RADIUS tool for earthquake damage estimations was developed by the RADIUS Tijuana Group to provide practical guidance on earthquake risk estimation and reduction. It is not designed to do real time estimations as it requires the calculation parameters (shape of target region, population distribution, building inventory and distribution, ground characteristics, earthquake parameters) to be entered manually. RADIUS will calculate the ground shaking distribution, building and lifeline damages, the human impact (dead and injuries) as summary tables and thematic maps (15).

The tool itself has been simplified to promote an understanding of earthquake damage estimations and should only be used for preliminary estimation and not for professional purposes.

NERIES / ELER

ELER is a tool developed within the EU project NERIES. It aims at assessing and recalibrating the estimation algorithm of Samardjeva and Badat by comparing the calculated casualty estimations of 712 past earthquakes with the actual numbers (16). ELER is not designed to do real-time estimations. As an outcome of the project, 88.48% of the 712 earthquakes were "well estimated", 8.71% were "overestimated" and 2.81% were "underestimated".

Post Disaster Needs Assessment

As shown in section 2.2 -- Damages up to large areas --, it takes usually much too long to receive a rough overview over the damages in complex situations (e.g. for the Haiti earthquake 19 days for a map indicating all damaged buildings), but this kind of information is necessary to assess in a next step the different needs that must be handled. **Error! Reference source not found.** shows the presented damage, loss and needs assessment tools comparing the time, needed for an assessment, the generated results, the updating process, the reliability, interoperability and notability. Most tools deliver a first assessment based on the measured event data such as peak ground acceleration for earthquakes. HAZUS is one of the most used tools of this category. Whereas tools such as the crowd-sourcing tool GEOCAN use observed damages and losses to upgrade the first assessments resulting in a more realistic understanding of the situation after the event.

By conducting an analysis on the various lessons learnt when dealing with such kind of damages resulting from disasters the speed to access the assessments and their respective reliability must be significantly enhanced (e.g. (17)). The Disasters Emergency Committee (DEC) explicitly demands a rapid 'one hit' multisectoral assessment tool (18) based on the experiences of non-governmental organisations, UN agencies and Haiti ministries. Too much time was spent, when each organisation individually tried to assess the different needs of local authorities. A point made by several interviewees concerning assessments was the set in of fatigue among communities that may have experienced several visits by sometimes the same agency focusing on different sectoral interests (18)."Sectoral interests" refers here to different tasks (e.g. construction of emergency shelters, clearing and debris removal etc.) a single relief organisation may provide.

Consequently the humanitarian community frequently expressed the need for a more harmonised approach to needs assessment (19), (20). At moment many organisations and projects try to build a common basis for a standardized post disaster needs assessment process. This is a very difficult task because there are many different organisations involved in assessment and recovery, governmental and non-governmental, national and international with different objectives and different assessment methods that are the result of their particular experience in their particular field.

Technical solutions for faster and more reliable post disaster needs assessment are urgently needed. In this respect, RECONASS is a further player in this field, concentrating on technical solutions. RECONASS must not define the standards for a new post disaster needs assessment methodology but has to follow the standards developed under the framework of the United Nations and the European Community.

Table 6 - Comparison of damage, loss and needs assessment tools

Tool / Method	Type of tool / summary	Time needed for assessment	Outcome of tool / method	Updating process	Reliability	Interoperability	Notability
GDACS	"GDACS works as a data exchange provider"	n/a	"GDACS alerts and automatic impact estimations"	"JRC establishes scientific partnerships with global hazard monitoring organisations". GDACS seems to be dependent on external data providers.	na (dependent on external data providers?)	Uses standarized data exchange formats	Used by "some 14,000 disaster managers" (vOSOCC)
AURIS	Research project under progress "Computer analysis of the data automatically collected by the system is conducted to establish the remaining structural capacity of the building"	real-time sensor data collection	"remaining structural capacity of the building"	real-time sensor data collection	n/a	n/a	n/a

HAZUS	"multi-hazard tool developed by FEMA for the prediction and mitigation of losses due to earthquakes, hurricanes and floods"	"near-real-time analysis capabilities for rapid post-event response"	"...estimate physical, economic, and social impacts of disasters. It graphically illustrates the limits of identified high-risk locations due to earthquake, hurricane, and floods. Users can then visualize the spatial relationships between populations and other more permanently fixed geographic assets or resources for the specific hazard being modelled"	n/a	n/a	n/a	"Government planners, GIS specialists, and emergency managers use Hazus"
COBACORE	Communication exchange platform to foster exchange of affected communities and responders	n/a	n/a	n/a	n/a	n/a	n/a
IASC Operational Guidance for Coordinated Assessments in Humanitarian Crises	methodology	n/a	n/a	n/a	n/a	n/a	n/a

VEBE	Tool for simulating impact of explosions and natural disasters on building level	no real time simulation, manual data input necessary and manually triggered	"It describes how pressure and blast debris act upon buildings (incl. shelters), humans and underground supply systems, how fire is initiated and spread inside and between buildings and finally how the damaged buildings affect humans and shelters"	manual data input	Simplified submodules for glass and non-structural walls.	n/a	Used by FEMA
WAPMERR / QLARM	Tool for real-time loss estimation after earthquakes	"less than two hours", average delay is 28 minutes	Estimated number of injured and fatalities as well as average damage to buildings. Sent as alert message (email) as well as a map showing the average loss in the affected settlements and a list of these settlements with differentiated loss estimates within each.	static?	Sumatra Earthquake 2005: "We warned that more than 1000 fatalities may have to be expected. The final number of fatalities reported was 1313."	n/a	Swiss Corps for Humanitarian Aid

PAGER / ShakeMap	Tool providing fatality and economic loss impact estimates following significant earthquakes	"PAGER results are generally available within 30 minutes of a significant earthquake"	Alert message, as well as supplementary information, including comments describing the dominant types of vulnerable buildings in the region, exposure and any fatality reports from previous nearby earthquakes, and a summary of regionally specific information concerning the potential for secondary hazards, such as earthquake-induced landslides, tsunami, and liquefaction.	"However, information on the extent of shaking will be uncertain in the minutes and hours following an earthquake and typically improves as additional sensor data and reported intensities are acquired and incorporated into models of the earthquake's source." "As subsequent information becomes available, more accurate maps of ground shaking are produced, refined estimates of population exposures are made, and updated alerts are issued, if necessary."	n/a	n/a	USAID, Red Cross

NERIES / ELER	Software to assess and recalibrate the performance of the casualties estimation algorithm from Samardjeva and Badal	unknown (software not designed to do real time estimations)	Casualties estimation of ~ 700 earthquakes. Outcomes to be compared with the real casualty numbers	n/a	88.48% of earthquakes "well estimated", 8.71% "overestimated", 2.81% "underestimated"	n/a	n/a
DESTRIERO	GIS based decision support tool designed for operational level, under development	Seems to be ongoing process, based on satellite and aerial imagery and field data collected with mobile apps	"Boost information sharing between relief organisations and their information systems for coordinated damage and needs assessment as well as reconstruction and recovery operations"	"Supports continuous damage and contamination assessment, monitoring and updating" "Supports prioritisation and joint decision making"	n/a	"DESTRIERO will offer a next generation post-crisis needs assessment tool, to collect data in interoperable formats"	n/a
Istanbul Earthquake Rapid Response System	"The Istanbul Earthquake Rapid Response System equipped with 100 instruments and two data processing centers aims at the near real time estimation of earthquake damages using most recently developed methodologies and up-to-date structural	"near real time" for first step: "rapid estimation of the ground motion distribution using the strong ground motion data gathered from the instruments"	Step three provides "estimation of building damage and casualties based on estimated ground motions and intensities"	Update of estimations in step two: "improvement of the ground motion estimations as earthquake parameters become available"	n/a	n/a	Istanbul city

	and demographic inventories of Istanbul city.". Seems to be a complex system of sensors, software etc.						
RADIUS	"The RADIUS tool was developed to provide practical guidance on earthquake risk estimation and reduction"	Not real time, data has to be entered manually	Ground shaking distribution, building damages, lifeline damages, human impact (dead and injuries) as summary tables and thematic map	manual data input (shape of target region, population distribution, building inventory and distribution, ground characteristics, earthquake parameters)	"The tool has been simplified to promote an understanding of earthquake damage estimation of decision makers and the wider public" "...the tool should only be used for preliminary estimation" "The tool requires only simple input data..." "To be used by city administrators and general public, not for professional purposes"	n/a	City of Kathmandu, city of Tijuana, city of Antofagasta

GEOCAN	"The development of web-based crowd-sourcing techniques… enabling a large team of experienced people to share the task of building-by-building assessment over a large damaged area, so that an overall assessment can be produced very rapidly"	"After the 2010 Haiti earthquake, the GEO-CAN team of more than 600 people was assembled by EERI within a few days of the earthquake, and produced a first damage map of the urban area of Port-au-Prince within a week of the occurrence of the event"	"...to make an approximate, but useful, early assessment of the overall damage" "..identifying buildings which have suffered earthquake damage" using satellite / aerial imagery	"building-by-building assessment over a large damaged area"	"94% of locations analysed as damaged in GEOCAN […] were also damaged according to field survey" "It should be noted that the commission error cannot be calculated in this case. A commission error would incorporate the number of buildings wrongly assigned a damage level by GEOCAN when there is no damage according to the field survey"	n/a	Used in Haiti and Christchurch earthquakes

1.4.3. Assessment of Structural Damage Due to Earthquakes, Explosives and Fire

Assessment of Earthquake Damage

Models for real-time estimates of earthquake damage to buildings are based on calculating the acceleration of ground motion in settlements near a reported earthquake and depend critically on accurate knowledge of the hypocenter and magnitude (21). Once these are known, fragility curves for typical buildings can be used to assess the building damage. For example, these are exploited in the method to estimate losses in the HAZUS software reviewed in section 1.4.2 above.

The above estimates can be useful to assess typical building damage and needs in an area but are not useful for the assessment of damage to a specific building. For the latter assessment a number of monitoring systems have been used.

Vibration based building monitoring offers the advantage that with only a limited number of sensors to monitor a large building it can provide global building assessment. The civil engineering community has studied vibration-based damage assessment of buildings and bridge structures since the early 1980s. Modal properties and quantities derived from these properties, such as mode shape curvature and dynamic flexibility matrix indices, have been the primary features used to identify damage in structures (e.g. (22), (23)). Although successful applications have been developed (e.g. see (24)and (25)) the vibration-based damage assessment of complex structures such as buildings remains a challenging task for civil engineers (26). The difficulties encountered in the damage assessment of complex civil engineering structures using vibration measurements are primarily due to insensitivity of modal properties of redundant structures to local damage, incompleteness of measured data, measurement noise, modelling error and uncertainty of environmental factors that contribute to modal frequency shifts (26). In (24) has clearly highlighted a general scepticism from the practitioners' world about vibration based damage detection, motivated by the poor quality of the information conveyed by classical sensor systems.

Additional monitoring techniques often include strain monitoring. These techniques are typically precise at localising damages but since the damage location cannot be predicted with accuracy they need to be deployed over large areas of expected damage for complete (both local and global) health diagnosis. Needless to say, typical such systems rapidly become economically infeasible as the scale is increased (27).

Contrary to the above, in the context of project MEMSCON (27). DBA has used a monitoring system consisting of only few strain and acceleration sensors that combined with an energy-based theory of seismic failure can accurately assess seismic damage of the monitored building at the component and building level in near real time. This system, which in the context of MEMSCON was useful for new buildings only, will be extended in the context of RECONASS to be useful for existing buildings as well.

The MEMSCON Project

The MEMSCON Project (27) is about a monitoring system, which consists of the least possible amount of strain and acceleration sensors combined with commercially available software for Finite Element non-linear analysis of building structures.

In the structural assessment module under operational conditions, which is only applicable for new buildings, the differential settlements between the footings are initially calculated from the recorded values of the three strain sensors per column that are installed only at the ground floor. Furthermore, the actual values of the live loads applied as well as the internal forces of the structural members with their relevant safety factor against their ultimate strength are computed.

In the structural assessment module for seismic actions, which is applicable for both new and existing buildings, the horizontal displacements' time history of the storeys is calculated from the recorded acceleration time history of the two 2-D accelerometers installed at every storey, which in turn constitutes the input data to the analysis software. By using an energy-based theory, the seismic damage degree of the structural members is then estimated.

Decentralization of Wireless Monitoring and Control Technologies for Smart Civil Structures

The dissertation about Decentralization Of Wireless Monitoring And Control Technologies For Smart Civil Structures (28)shows how it is possible to use the wireless sensing unit for modal analysis of the structures in which they are installed by writing a software application to calculate the frequency response function (FRF) from time history measurement data. While wire-based monitoring systems would typically perform such calculations at a centralized data server, the FRF application can be embedded and executed in the wireless sensing unit.

Modal Analysis Procedures

Modal testing and analysis used to identify a mathematical model of a structure, is widely used in the civil engineering community. Often, the intent of the engineer in using modal analysis is to validate the use of finite element models that have predicted dynamic response levels of the structure. For such applications, all that is required are the natural frequencies of response and complete descriptions of the associated mode shapes. Sometimes, modal testing is used to directly calibrate an analytical model. For example, insight to the damping of the structure can be gained from modal testing, resulting in improved models better calibrated to test data. Historically, modal analysis methods have played a major role in the development of damage detection methods for structures. Significant research efforts have focused on using changes in the natural frequencies and mode shapes to identify the existence of damage in a structure. Frequency shift methods have been successful in structural environments where shifts can be measured in a precise manner such as in manufacturing machinery. Unfortunately, the environmental and operational variability of civil structures is a contributor to natural frequency and mode changes rendering the changes as the basis for damage identification difficult for civil structures except in cases where extreme damage is sustained. Modal analysis theory provides a means of identifying mathematically the free response of a dynamic system by a set of frequencies and mode shapes known as the modal properties of the system. The analysis framework also provides a means of characterizing the forced response of a system through a set of frequency-domain transfer (mobility) functions relating the response of a system with its forcing function. Hence, transformation of system time-histories (response and excitation) to the frequency domain is required. Once in the frequency domain, various modal parameter extraction methods are available that find coefficients of a theoretical expression for the frequency response function (FRF) matching the FRF obtained from the measurement data.

Fast Fourier Transform Procedures

The FRF of a structural system can be calculated directly from measurement data by using the computationally efficient fast Fourier transform (FFT). The discretely measured response of a system in the time domain is converted to the response frequency domain by means of a discreet Fourier transform.

Statistical Pattern Recognition

In (22), propose using time-series analysis for the identification of damage in civil structures. It is part of a damage detection framework which consists of four-parts: evaluation of a structure's operational environment, acquisition of structural response measurements, extraction of damage sensitive features and use of statistical models for feature discrimination (22). The time-series approach has shown promise in the identification of damage in the hull of a high-speed patrol boat as well as in several laboratory test structures. As a result of the approach addressing the environmental and operational variability of civil structures, it is selected to be embedded within the wireless sensing units.

Long Wave Infrared Rays (LWIR) Thermography

Explosions and fire eruptions will produce fire damage to structures. LWIR thermography enables continuous monitoring of the surface temperature. To achieve that, IR video images are recorded with special cameras and then get electronically processed and analyzed. It can be used across wide and long distances of up to several hundred meters, Using LWIR thermography; temperatures can be measured via each individual pixel of a video image. With this method, the person viewing the image is provided with a representation of the object, including precise temperature values for every point on its surface.

Two wavelength ranges of infrared radiation can be used in thermography. In the IR wavelength range (3-5µm), transmission strongly depends on the extent to which the atmosphere is contaminated with airborne particles. Consequently, this wavelength range is not suitable for providing the accuracy needed when measuring temperatures for the early fire detection, despite the availability of cost-efficient sensor technologies. In the LWIR wavelength range from 8-12µm, a large portion of the aerosols, such as fog or smoke that occur in many applications are almost transparent. In contrast to conventional monitoring cameras (CCTV) or the human eye, which both utilize much shorter wavelengths; this allows an LWIR camera to virtually “see through the smoke”. Even across distances of 500m and greater, the signal is not susceptible to any considerable attenuation. Moreover, wavelength fluctuations due to temperature changes do not cause absorption-induced fluctuations in the signal strength that might be mistaken for changes in the actual radiation intensity. As a result, this technology can also be used in environments with high aerosol concentrations and provides valuable support in fighting fires.

Only the LWIR wavelength range presents optimal conditions for temperature measurement. The temperature measurement ranges can extend from below -20°C to much higher than 1000°C. The temperature can be determined to 1K. Increased or excessively high temperatures can be precisely measured, regardless of the ambient temperature. This provides ideal conditions for the early detection of fires.

The invisible LWIR radiation can be made visible using today’s video post processing methods. For this purpose, a colour is assigned to every measured temperature value, resulting in a false colour image, such as those known from the thermal inspection of facade insulations. “Warm” colours (e.g. red) indicate high temperatures, whereas “cold” (e.g. blue) colours are used for low temperatures. As a result, the distribution of the surface temperatures becomes visual and can be evaluated at a glance to immediately assess the situation.

In order to be able to visualize, in any situation, the relevant temperature range with the limited contrast range of both video technology and the human eye, this method recalculates and reassigns the temperatures and brightness values for every new image. Consequently, the temperature cannot be evaluated based on the video images, and therefore, selected alphanumeric temperature values are displayed in addition.

Such a detection system is the ARTUS System. ARTUS is a fully automatic temperature measuring and monitoring system. It uses a modern LWIR microbolometer camera (long wave infrared) to precisely measure surface temperatures at accuracy of up to 1K using a contactless method. ARTUS automatically and continuously checks the monitored area to make sure it is within the specified temperature thresholds and detects potential hazards if the thresholds are exceeded.

1.4.4. Damage, Repair Needs and Functionality of Building Components

A building is composed of structural and non-structural components (for definitions of terms, see Glossary). The Figure 11 shows the relative value of these components. It can be seen that the value of non-structural components exceeds the value of structural components.

Structural Components

The assessment of damage in structural components has been reviewed in section 1.4.3 above. Based on structural damage due to an earthquake, blast/impact, fire, one can assess repair needs and building functionality.

For seismic damage there are many programs on loss estimation, e.g., HAZUS or the PACT software of the US project ATC-58 (30) that based on hypothetical earthquakes and with the use of fragility curves for typical buildings estimates loss of functionality and repair needs (31).

Of course, when there is an analytical structural assessment based on sensor measurements from a monitored building the above can be assessed far more credibly based on the results of structural analyses.

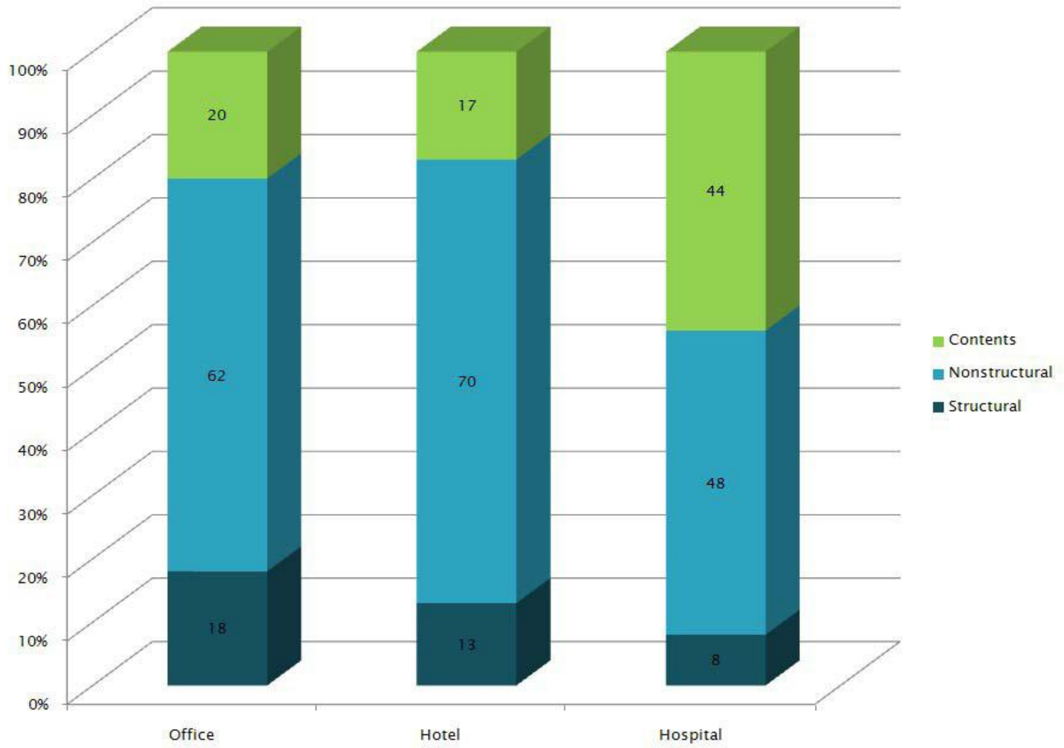


Figure 11: Typical Investments in Building Construction (Please note that 'Contents' are out of scope of RECONASS) From FEMA E-74/January 2011.

Non-structural elements

The list of non-structural building components is nearly endless and constantly evolving, as new technologies alter the built environment. It would be impractical to develop a performance prediction methodology that explicitly considered all the components that exist in any one building, let alone the entire inventory of buildings that must be addressed. The first step then, has to be an identification of components that have particularly important and significant consequences with regard to life loss or serious injury, repair costs and downtime and categorise them into several broad groups which have similar performance characteristics and their response to earthquake loading is determined by the same parameters. Similarly, an identification of components is needed which have a lesser impact and similarly categorise them. Such a building categorisation system (or taxonomy) has been developed in the ATC -58 Project (30) , which is also accepted for use by the international project GEM (32).

The ATC-58 taxonomy (as well as the GEM project) is developed for earthquake risks. In RECONASS the taxonomy based on the ATC-58 project has been deemed appropriate for the blast/impact loss that will be estimated in this work as well as the loss due to fire.

Most non-structural components, unlike structures, are not directly affected by the ground shaking, but rather are affected by motion or shaking of the structure to which they are attached or upon which they are supported. Accordingly, for non-structural components the first step of the assessment process is to determine the parameters that describe the response of these components to earthquake shaking transmitted to them by the supporting structure.

Many non-structural components act essentially as rigid bodies and have no response that is distinctly different from the motion of the structure that supports them. For these classes of non-structural components peak interstory drift may be used directly to predict non-structural performance. However, some non-structural components have inherent flexibility and will either amplify or attenuate the motions transmitted to them by the structure and in the process, will experience motions that are different from those experienced by the supporting structure. In this case peak floor acceleration can be used to assess non-structural performance. The Table below provides examples of parameters that can be used to assess component performance in the case of earthquake shaking Example of Parameters Describing Response of Non-structural Components to Earthquake Shaking:

Table 7: Parameters describing non-structural elements

Component/System	Parameter the describes response to earthquake shaking
Precast Concrete Wall Panels. In-Plane Damage	Interstory Drift Parallel to the Wall
Precast Concrete Wall Panels. Out-of-Plane Damage	Peak Floor Acceleration in the Direction Normal to the Wall at the Top Floor Adjacent to the Panel.
Exterior Window Systems	Interstory Drift Parallel to the Wall
Interior Partitions	Interstory Drift Parallel to the Wall
Suspended Ceiling	Peak Floor Acceleration

Project ATC-58 covers common components in the US market for which it provides structural response parameters, damage states, repair needs and functionality. The above do not include unreinforced non-load bearing masonry walls, prevalent in reinforced concrete buildings in the seismic prone countries of Europe and elsewhere (e.g., Australia and New Zealand). Yet, the assessment of damage to the above walls is important for RECONASS because, inter alia, it is information from the monitored building facade that will be used to calibrate and validate airborne imagery that will then used to efficiently improve synoptic damage assessment based on space borne imagery. Such an assessment will be developed in this work which is possible because of relevant work in Australia and New Zealand (e.g., see (33); (34); (35); (36)and (37)) and because of structural analyses in this work that will provide measurements of the movements of the four corners of such walls in the horizontal direction.

The damage states resulting from seismic loading will also be useful for blast/impact loading in this work: Based on the local positioning tags before and after an extreme event, the structural and non-structural components that will be beyond the point of practicable repair will be determined. Damage to the remaining components will be due to blast induced vibrations that, just as in the case of seismic vibrations, will cause interstory drifts, floor accelerations, etc. that produce the various damage states.

The fire resistance of building elements is commonly determined by conducting laboratory tests following the procedure laid down in national and international standards. The technique used in the determination of fire resistance is to expose a prototype construction element (sample) to standardised heating conditions. Measurements are made to determine the duration for which the construction element fulfils certain prescribed criteria related to its intended use.

The heating environment to which the sample element is exposed in special designed furnaces follows a standard time/temperature relationship (e.g., curves EN 1202, ISO-834, BS476, etc.). Based on the above, there are published limits in terms of time of exposure or the maximum temperature of the fire for the building elements. For instance, ICC 2000, chapter 7 on fire resistance ratings provides such ratings in terms of hours of exposure for precast concrete non load bearing walls while ASTM E119 and EN 1990-1-2 provides fire resistance ratings in terms of hours of exposure to fire for unreinforced non load bearing masonry walls. On the other hand the damage limits for Aluminium panels, doors or windows are based on the maximum temperature reached during a fire (e.g., see (38)).

1.4.5. Necessary Improvements in the field of Damage, Loss and Needs Assessment Methods for recovery and reconstruction planning - Conclusions

In the field of Damage, Loss and Needs Assessment Methods for recovery and reconstruction planning, the challenges and necessary improvements beyond the state of the art were indicated in the respective sections above.

A wide range of tools to support the post disaster needs assessment is available, but any solution must fit in the standards that are developed at moment under the framework of the United Nations and the European

Community. There is an urgent need of technical solutions combining the results of damage simulation and assessment, damage assessment based on measurements in affected buildings, aerial imagery based damage assessment and needs assessment based on observations.

A first damage assessment based on inventory and event data is provided by many tools such as HAZUS or GDACS. But to it takes usually much too long to receive a rough overview over the damages in complex situations (e.g. for the Haiti earthquake 19 days for a map indicating all damaged buildings) derived from the observations of different stakeholders. To coordinate the first disaster response activities, maps indicating damages and urgent response needs should be available after 24 to 48 hours. This gap between the first automatic assessments and the observation based information can be filled by recalibrating damage and loss assessments with the observations of the occurred damages.

Especially in the field of damage assessment for non-structural elements of a building exposed to fire, explosions or seismic load there is a need for technical solutions. The results of the different damage and needs assessments must be available after minutes and hours, depending on whether urgent response needs the information or it is the base for the recovery and reconstruction planning.

Following the preceding information, necessary improvements in the field of Damage, Loss and Needs Assessment Methods for recovery and reconstruction planning for the RECONASS project are (Table 8):

Table 8: Requirements in the field of Damage, Loss and Needs Assessment Methods for recovery and reconstruction planning

Nr.	Requirement	Specific domain involved
2.1.	Interoperability with GDACS must be ensured.	Post earthquake response and recovery
2.2	Standardized interfaces for communication and data exchange with actual common data exchange platforms such as GDACS and VirtualOSOCC	Post earthquake response and recovery
2.3	Results of comparable research projects must be monitored to ensure standardized interoperability	Post earthquake response and recovery, all RECONASS research areas
2.4	VEBE damage assessment tool to be used for the damage simulation	Damage simulation and assessment
2.5	Standardized interfaces for communication and data exchange with local damage assessment systems such as HAZUS	Damage simulation and assessment
2.6	Structural damage assessment must consider the structures of specific buildings	Assessment of structural damages
2.7	Vibration based damage assessment and strain monitoring must be combined to achieve reliable and precise results	Assessment of structural damages
2.8	Sensor networks and damage assessment must be applicable to already existing buildings (after the construction phase)	Sensor networks, and assessment of structural damages
2.9	Structural damage assessment based on sensor measurements enhances credibility and assessment quality	Assessment of structural damages
2.10	The non-structural elements must include unreinforced non-load bearing masonry walls	Assessment of non-structural damages
2.11	The assessment of the damages must be calculated within minutes after the event	Damage simulation and assessment
2.12	The assessment of building functionality, repair needs and generated debris must be calculated within few hours	Damage and needs assessment

1.5. Synergistic Damage Assessment with Air and Space borne Remote Sensing

Numerous methods have been reported for remote sensing based building damage assessment. The reported methods can be categorised into two groups: 1) damage assessment by analysing the significant changes between the pre and post event image data and 2) damage assessment by analysing the post event data alone. The limitation with the former approach is the availability of pre-event data with required characteristics that are compatible for post event data comparison. In the context of RECONASS, a detailed damage assessment has to be carried out for a single building even in nonexistence of pre-event data. The methods based on the post-event data are appropriate for damage assessment in RECONASS. All the methods are based on the generic pipeline: feature extraction from the images followed by classification for damage assessment.

Various features such as spectral, texture, edges, shape, size, contextual features, etc., have been reported as the potential features for detecting the damaged buildings in the post event data (39). Most of the reported methods are based on vertical view satellite data and their major concern is to delineate completely collapsed or heavily damaged building. The satellite image based damage assessment is often as reported not being accurate enough or to under or overestimate the overall damage of the buildings (40). This is due to the major limitation of remote sensing based building damage detection as most of the remote sensing data provide a quasi-vertical perspective of the scene in which damage along the facades and lower grade damages other than to buildings roofs cannot be detected as they are not visible (41).

1.5.1. Multi-view oblique airborne imagery

The airborne oblique images which are captured at a large tilt angle with multiple views can provide more information about the facades of the buildings when compared to nadir or near nadir images. Airborne oblique images have been identified as a potential data source for accurate building damage assessment as they can provide high level and multi-view information of both façades and roofs thereby accurate damage assessment. In (42) Kerle and Ozisic synergistically combined vertical satellite data and oblique imagery for damage assessment and reported that oblique images were more significant to detect the damaged areas. In (41) Gerke and Kerle demonstrated the building damage assessment using the oblique airborne data. They adopted the Adaboost supervised classification scheme based on 22 image derived features including textures of optical and depth image, colour, line features and 3D features for individually classifying all images corresponds to specific view into façades, intact roofs, destroyed roofs and vegetation and then integrated the damage results derived from all single view images to arrive at the final damage score at per building level based on European Macroseismic Scale (EMS 98).

In (43) Gerke (2011) reported that 3D supervised image classification in object space improved the classification results when compared to the method adopted in (41) Gerke and Kerle for building damage classification. All the reported methods assess the damage state of the building as a whole and assign the single damage label for the entire building even if only a specific portion of the building is severely damaged. For RECONASS, an element-specific detailed building damage assessment is required, which has not been done yet using the remote sensing images. The element-specific damage assessment requires the generation of a semantic-rich inventory of the building and damage state along each element of the building. Recent studies have shown that unstructured 3D point clouds can be used to automatically recognize the structural components of the buildings even in the presence of significant clutter and occlusion (44). It has to be analysed how these methods can be applied for mapping the structural elements of the buildings under damaged condition.

The 3D point clouds from the multi-perspective, oblique and high overlapping images from Unmanned Aerial Vehicle (UAV) or manned aerial vehicle seems to have potential for generating detailed inventory of the building for damage assessment. UAVs have become an increasingly popular data source for photogrammetric processing, which combines the advantages of both terrestrial and aerial photogrammetry as it can be operated at lower altitude remotely controlled, semi-automated or autonomous with no human pilot on-board. The UAV systems possess potential advantages when compared to manned aerial vehicle especially when concerned for local area applications where repetitive, fast and cost effective data collection is required.

The major advantage of UAV is that it can be operated in high risk environment and inaccessible area which reduces the life risk of pilots. The UAV system is capable of providing very high spatial resolution data as it can operate at lower altitude and also can capture data with high overlap at multi-view direction (nadir and oblique), which is a prerequisite for the generation of high quality photogrammetry products such as orthoimages, digital surface models (DSM), dense 3D point clouds, etc. Very few studies so far have investigated the potential of LiDAR 3D points clouds for damage assessment and no significant research has been carried out for damage assessment based on 3D image point clouds. The 3D image point clouds are capable of providing radiometric features in addition to geometric features when compared to LiDAR. Significant methodologies have to be developed that utilize the advantages of multi-view oblique airborne images based 3D point clouds for more accurate and reliable damage assessment.

1.5.2. Satellite and airborne information gathering

Satellite images have been traditionally providing data for generating damage maps for larger areas in case of major disaster events such as earthquake. The satellite-based damage assessment for an extensive area was often found to be under or overestimated due to variety of reasons as discussed before. Also it is very difficult to obtain timely ground information for validation and calibration of satellite based damage maps. In (45), it has been improved the damage assessment made by vertical satellite images using much smaller samples of assessment from oblique images and ground observations using Bayesian statistics methods. In RECONASS, the damage assessment based on the multi-view oblique images for the monitored and the neighbouring buildings could be used as ground observations for improving the (vertical) satellite based damage maps. An optimal procedure has to be developed for such calibration and validation of satellite-based damage maps using the local damage assessment from the UAV images. The other important task related to RECONASS is the mapping of debris from the satellite images which can be used along with the digitised road maps to monitor the status of the road networks (e.g. open/blocked roads) connected to the monitored building. The mapping of debris from satellite images has been attempted by various studies and achieved significant accuracy (39). It has been inferred that the detection of debris is very difficult in dense urban environment as the cues derived from remote sensing images are highly uncertain since debris has no specific shape, pattern and texture and often large rubbles are misclassified as intact building segments, since they possess more similar spectral and geometrical characteristics of buildings (46). The 3D height information is required to quantify the debris or rubble piles. The 3D information that can be generated from the point clouds of UAV images or satellite stereo images can be used to quantify the rubbles and debris. The reliable methods have to be developed based on the advanced pattern recognition algorithms and 3D features for accurate rubbles/debris mapping and quantification.

1.5.3. Multi sensor assessment

The objective of RECONASS is to maximize the synergistic advantages of both image and wireless sensor based damage information like improving the overall assessment, as a complimentary data for calibration and validation of damage assessment based on each technology and filling the gaps of one technology with the other. Two major challenges related to this objective are 1) locating the position of sensors in the image and 2) correlation of remote sensing images and WSN based damage assessment. The sensor positions contained in the annotated 3D model of the building can be used for mapping the sensors' locations in the images by 3D model to 2D image registration techniques. The geometric features such as points or lines can be used to register the 3D model with the 2D image, but the challenging task here is the extraction of accurate and reliable geometric features from the images. The second challenging task is the correlation of WSN and image based damage assessment which is especially required for filling the information gap due to failure of any sensors in the network. It has to be analysed whether the image based damage information can be directly correlated with the physical sensor measurements (e.g. displacement) or can be related only with the damage classes provided by the structural assessment module. In this research new methodologies have to be developed for correlating the WSN and image based damage assessment for improved assessment and filling the gaps of missing sensors' information. Similarly the procedure for calibration and validation of image based damage assessment using the WSN based damage information has to be developed and vice versa.

1.5.4. Conceptualization of sensor network extension

The other sensors like chemical and biological sensors have a potential application in damage assessment which can be used to monitor the presence of any harmful chemical or biological agents in the disaster environment as part of damage assessment. For example in case of disaster events such as industrial explosions, war and terrorist attacks, the release of chemical or biological agents may be possible which may be very harmful to human beings in the vicinity, especially for the people involved in the rescue operation. In such cases determining the location and intensity of the chemical or biological agents is important as it can act as an early warning alarm for the relevant stake holders. The potential region and people that may get affected from the chemical agents can be estimated with the readings from the sensors and other auxiliary information like the wind speed, direction and population density around the region. Recently developed electro-chemical sensors that are physically small, show low power consumption, that are portable and operate in real time would be suitable to be added along with other sensors in the existing sensor network (47). A framework has to be developed to integrate the potential biological and chemical sensors with the existing sensor network to provide time critical information for relevant stake holders.

1.5.5. Necessary Improvements in the field of Synergistic Damage Assessment with Air and Space borne Remote Sensing - Conclusions

Actually the use of UAVs is a new development in the field of emergency response. Legal aspects and public opinion make this development even more difficult. But only with the use of all available data especially when comparing the information from different sources, a fast and reliable understanding of the situation after such events is possible.

The image data cannot be captured in bad weather conditions and also UAV drone cannot be effectively operated in the windy environment. It will take considerable time to collect UAV data as the flight expert needs to visit the affected area to setup the UAV drone flight. It may take few days to get satellite data which depends on the data provider.

Additional to the determination of the overall damage state of a building, responders may be interested in detailed imagery of sources of falling hazards or openings to access victims or indicators of damages such as cracks or displacements. Due to this reason flights at different times depending on the tasks to be fulfilled may be necessary.

Following the preceding information, necessary improvements in the field Synergistic Damage Assessment with Air and Space borne Remote Sensing for the RECONASS project are:

Table 9: Requirements in the field of Synergistic Damage Assessment with Air and Space borne Remote Sensing

Nr.	Requirement	Specific domain involved
3.1.	Legal conditions must be fulfilled.	UAV used to generate oblique airborne imagery
3.2	Public opinion must tolerate the use of “drones”	UAV used to generate oblique airborne imagery
3.3	UAV Operators need time to reach the affected area	UAV used to generate oblique airborne imagery
3.4	Actual satellite data is available after hours or days	Air and space born remote sensing
3.5	Oblique imagery is necessary to detect damages below roof level	Damage detection
3.6	3D point clouds from the multi-perspective, oblique and high overlapping images are necessary for detailed damage assessment	Damage detection
3.7	Low flying UAVs can provide high resolution	Support for response teams

	imagery that is necessary for search and rescue organisations	
3.8	UAVs do not put pilots at risk	UAV used to generate oblique airborne imagery
3.9	Further development in terms of accuracy, reliability and use of radiometric and optic sensors is necessary	Airborne sensor technology
3.10	Satellite and airborne information gathering must be combined to reach a high level of information quality and reliability	Damage detection
3.11	Volumes of debris and collapsed buildings must be measured	Damage detection (roads and buildings), needs assessment
3.12	Imagery must be used to improved the damage assessment based on sensors in buildings	Sensor networks, and assessment of structural and non-structural damages
3.13	Building sensors must be located in the images generated by UAVs	Multi sensor assessment
3.14	Correlation between building sensor network position data and the 3D model derived from airborne imagery	Multi sensor assessment
3.15	The possibility to extend the building sensor network with disaster/emergency relevant chemical and biological sensors has to be investigated	Sensor network extension

2. SPECIAL INCIDENTS DATA

The RECONASS system's structural and economic loss and needs assessments will be validated through a realistic scenario-pilot emulating the behaviour of a real structure made of reinforced concrete. In this section for the purpose of deriving useful lessons learnt from various incidents where buildings in which RECONASS could be applied either as an extended version or as it is we will provide specific examples. The requirements deriving from these examples are analysed and collected.

2.1. Collapse of single RC buildings: the Murrah Building

The Murrah Building in Oklahoma City was a nine storey public administration building which was damaged by a terroristic bomb attack on April 19, 1995 (see Figure 12). The bombing killed 168 persons and injured more than 680 others (48).

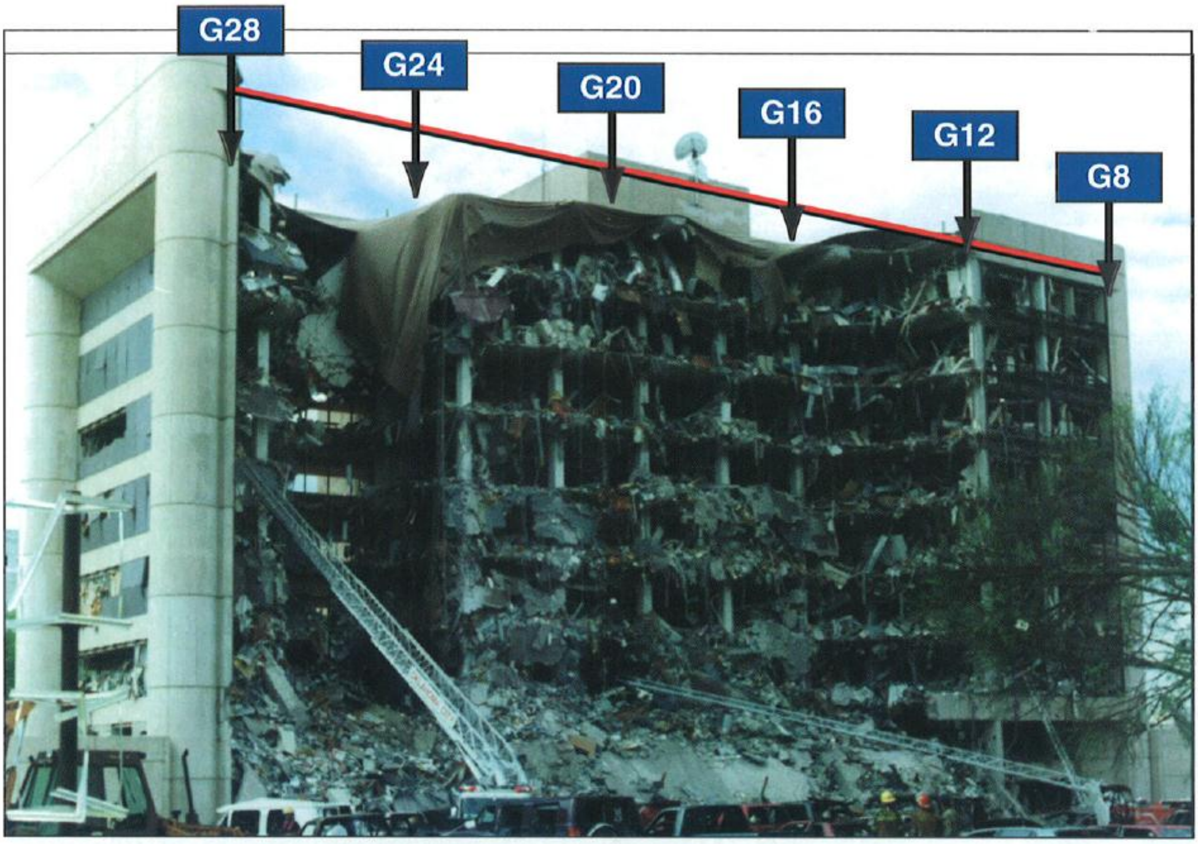


Figure 12: Damages to north and east sides of Murrah Building (48)

A truck bomb exploded outside the building. The blast wave lifted the floors and damaged the connections between columns and floors. These damages of the reinforced concrete construction lead to a partial collapse of the building. Some floors collapsed inside the remaining structure leading to triangularly shaped voids where survivors were found. The debris stabilized the structure and thus prevented a secondary collapse during rescue activities (Figure 13 left). The remaining building structure was internally shored up and braced to protect the rescue activities.

It is very time consuming and dangerous to reach such damaged structures within the collapsed building to assess the stability of the structure and to decide about further measures such as shoring or evacuation. Some of these points of interest to assess the stability are covered under debris, others are at high positions and can only be examined from above using a fire service turntable ladder or a helicopter or an UAV.

Even if it is possible to observe the structure, the actual forces and stresses within the structure cannot be assessed exactly in complex situations that mostly derive from partial collapses. During the rescue activities, debris and damaged parts of the building have to be moved. This leads to changes and sometimes instability of the static system. Monitoring of the stresses within the structure and movements of relevant parts within the structure is necessary to secure the rescue activities. The structural assessment is necessary as fast as possible because rescue activities will be delayed otherwise and rescuers are exposed to additional risk.

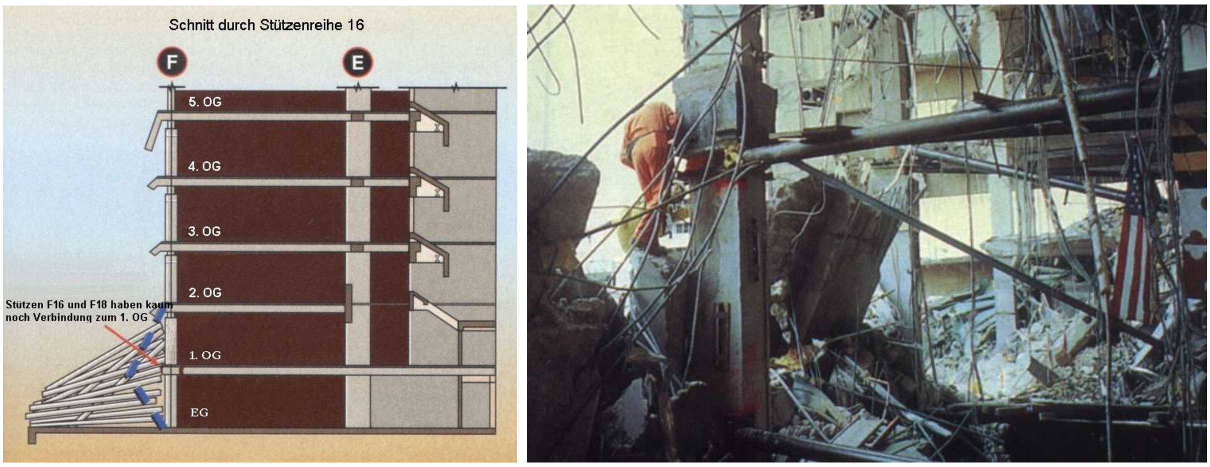


Figure 13: Damages to the Murrah Building and shoring measures (48)

There are up to now no examples of partly collapsed buildings, where a damage assessment based on preinstalled sensors could be performed. The described example shows, that such a system with the capability to monitor stresses or strains within the structure and monitor the displacement of inaccessible structures would significantly enhance safety of rescuers and victims and speed up the assessment and rescue activities.

2.2. Damages up to large areas

Two cases are analyzed here to better understand the environment, where the RECONASS system will work and to determine the current shortfalls and misfits.

2.2.1. Introduction

The earthquake that struck the Abruzzo region of Italy, at 3:32 am on April 6 2009, had a magnitude of 6.3. It caused significant damage to the city of L'Aquila and more than 20 surrounding villages. 308 people died during the earthquake, at least 1.500 were injured.

The impact on both residential and public buildings was significant. 15.000 buildings were severely damaged or collapsed, including nearly 70% of all buildings in L'Aquila. 70.000 to 80.000 inhabitants were temporarily evacuated, between 24.000 and 34.000 were left homeless (57). The regions primary hospital was temporarily closed due to structural damages. Other strategic buildings like the police headquarters also suffered significant damages. The infrastructure such as roads, bridges, gas and water pipelines also suffered damages from the earthquake (49).

Less than twelve month later, on January 12, 2010, a severe earthquake of magnitude 7.0 occurred in the Atlantic Ocean approximately 15 miles southwest of Port-au-Prince, Haiti. Port-au-Prince, the capital of Haiti and numerous other towns and cities suffered massive damage. According to the Government of Haiti, the earthquake collapsed 100.000 structures and damaged another 200.000 across Haiti, resulting in over 220.000 deaths, 300.000 injuries, and 1.1 million displaced people (50).

2.2.2. Rescue and recovery

Although many countries offered help after the L'Aquila earthquake, only few international resources were accepted by the Italian government. Rescue and damage assessment were conducted primarily by national teams of engineers. The Virtual OSOCC, a joint UN and EU internet communication platform, mentions 1.150 Italian experts organized in 495 teams conducting damage evaluation after the earthquake. Eight engineers from Russia's EMERCON and another eight experts of the European Community Mechanism of Civil Protection were supporting the assessment efforts (51).

Things were more serious in Haiti, the poorest country in the Western Hemisphere. Being overwhelmed not only by the massive destruction itself but also by the lack of national resources, nearly all rescue, recovery and coordination efforts had to be conducted by the international community, including more than eighty USAR teams and about 15 assessment and coordination teams (51). Vital infrastructure necessary to respond to the disaster was severely damaged or destroyed. This included all hospitals in the capital, air, sea, and land transport facilities and communication systems (52).

2.2.3. Assessment of structural damages

Comparing the reports from both earthquakes, it is obvious that the L'Aquila earthquake had a far lesser impact on the affected population than the Haiti earthquake. The affected L'Aquila region is relatively small, allowing sending resources from neighbouring and less affected regions. There is no lack of trained experts and equipment for rescue and damage assessment activities in a modern and wealthy developed country like Italy (51), (53).

In Italy, on January 29, the management was officially handed over from the Head of the Department of Civil Protection to the Deputy Commissioner for Reconstruction, the president of the Abruzzo Region. The assessment of the damages on public buildings like schools and hospitals started immediately after the earthquake and lasted only a few days. From the second day after the earthquake, the assessment on private buildings started. The state of emergency ended August 31 2012, from September 16 2012, the reconstruction and any necessary steps to promote and ensure the return to normal living conditions started (53).

The impact of the Haiti earthquake on the affected population was unlike bigger. Being one of the poorest countries in the world with unstable political conditions and only rudimentary governmental institutions, Haiti suffered heavily from the lack of local resources and capabilities to deal with the massive impact. On 22 January the United Nations noted that the emergency phase of the relief operation was drawing to a close, and on the following day the Haitian government officially called off the search for survivors.

The recovery and reconstruction in Haiti went slow and still is not finished. Six months after the quake as much as 98 percent of the rubble remained uncleared (52). In July 2010, CNN returned to Port-au-Prince and reported, "It looks like the quake just happened yesterday", and Imogen Wall, spokeswoman for the United Nations office of humanitarian affairs in Haiti, said that "six months from that time it may still look the same." In September 2010 there were over one million refugees still living in tents and the humanitarian situation was characterized as still being in the emergency phase.

After the Haiti earthquake, high resolution satellite imagery was used by remote assessment experts to compare pre- and post-earthquake images in order to estimate the severity of structural damages. The first two remote assessment phases were finished on January 17 and February 15 2010. The full extent of damages in Haiti was not known until finishing the final phase after 19 days, it covered an area of about 600 km2 and detected over 30.000 damaged or collapsed building. The major problems of this remote assessment procedure are the need to calibrate the results according to local construction methods and techniques, the impact of limited air traffic and a certain level of impreciseness due to misinterpretation of buildings under construction and collapsed structures with roofs remaining intact. Although this method proved useful for detecting building damages and estimating potential losses of structures and repair and rebuild costs, it is insufficient without on-site assessments by structural engineers, especially for key infrastructure like hospitals and airports (54). The European Commission Joint Research Centre, United Nations and World Bank collected the observations of different organisations and released a comprehensive building damage Atlas on March 17th, 2010, more than 2 months after the earthquake.

There was no single assessment tool but an international effort to use all available sources to produce this comprehensive atlas as a basis for the reconstruction planning.

Before the earthquake, Haiti lacked adequate GIS datasets to support detailed loss estimation (55) HAZUS and comparable tools based on local inventory data were not implemented, when the earthquake hit the area. With the collected inventory and damage data after the event, calibrations were performed resulting in a comprehensive data base for further events. The influence of possible seismic design codes and rebuilding scenarios on the vulnerability of the future building stock could be demonstrated and accordant proposals were made, but more than one year after the event.

Both disasters showed that even with enough national resources and expertise to assess the disasters impact, it still takes its time to get a clear picture of the amount and severity of the damages of infrastructure and buildings. For instance it took 19 days after the Haiti earthquake detect the full extent of damages. There always is vital infrastructure that is necessary to respond to the disaster like hospitals looking after injured people, police headquarters and fire stations taking care of security and rescue measures, and administration offices needed for coordination. Having a clear picture of their degree of damage is essential to get these key facilities running again as soon as possible.

3. USER REQUIREMENTS

3.1. Introduction

Preliminary user requirements for the RECONASS system base initially on the state of the art analysis and the analysis of the disaster events in Haiti 2010 and the region of L'Aquila/Italy 2009 and the Oklahoma City bombing. In order to further develop and specify these preliminary requirements by the input from end-users, the RECONASS partners as well as experienced THW members designed a RECONASS end user requirement questionnaire.

In parallel, a specific "RECONASS related" user group was established aiming at constantly accompanying the RECONASS project process. The group consists of different end-users, coming from RECONASS related fields of activity, as e.g. planners and operators of buildings and of the technical infrastructure, members of emergency and disaster response organisations, providers of damage maps, insurers and further stakeholders.

The members of the user group were asked to complete the RECONASS end-user questionnaire. They were invited to a first RECONASS end-user workshop in order to concentrate on the refinement of the user requirements and to consolidate them.

From the incoming feedback of the RECONASS end-user questionnaire, the first 19 answers were used to elaborate a first set of preliminary user requirements intended to be the basis for the user workshop that is described in deliverable 1.2.

Based on these steps, a first list of preliminary user requirements with 102 entries and a related classification system was created. The classification of the user requirements comprises the classification of the RECONASS sub-systems, the relevant user types, different functional and non-functional requirement types and the classification of the necessities (must, should, could, wont) and is described in the following sections.

The outcome of deliverable 1.1 is the basis for the upcoming tasks and continuing work and will be constantly evaluated and further developed within the RECONASS user group and with the assistance of the RECONASS partners.

3.2. The questionnaire

In order to derive first user requirements, a questionnaire was created in cooperation with all RECONASS consortium members and sent out to the first organisations that were invited to join the user group. There are two versions of the questionnaire (see Annex) for the different user types (see section 3.4)

The document was built as .pdf document with the functionality to collect user entries and export it to other applications. Some documents were printed out and sent back by email.

Some questions use the MoSCoW requirements attempt:
M - MUST: Describes a requirement that must be satisfied in the final solution for the solution to be considered a success.
S - SHOULD: Represents a high-priority item that should be included in the solution if it is possible. This is often a critical requirement but one which can be satisfied in other ways if strictly necessary.
C - COULD: Describes a requirement which is considered desirable but not necessary. This will be included if time and resources permit.
W - WONT: Represents a requirement that stakeholders have agreed will not be implemented in a given release, but may be considered for the future. (Note: occasionally the word "Would" is substituted for "Won't" to give a clearer understanding of this choice)

To better understand the scope of the planned work, the questionnaire was sent to the users together with the actual RECONASS project flyer.

3.3. The RECONASS System

The planned RECONASS System is mainly designed for earthquake events, explosions and fires. For a better comprehension of the RECONASS modular approach and the respective functionalities it could be divided into the sub systems described below:

1. A **sensor network** to be integrated in **critical buildings of** such as hospitals, fire stations or important transportation hubs. It includes an evaluation unit to assess the structural damages (with and without collapse), direct economic loss and needs of repair. Sensor measurements and damage assessments will reach the base station at real time, so, e.g. the Department of Health will know almost immediately after an earthquake if monitored hospitals are safe.
2. **Calibration of damage and needs assessment maps** derived e.g. from satellite or aerial images using the detailed assessments of monitored buildings and additional **multi view oblique airborne imagery acquired by an unmanned aerial vehicle (UAV**), provided with a likely time delay of 1-2 days due to equipment deployment to the incident site.
3. A **post-crisis needs assessment tool** in regards to construction damage and related needs (PCCDN) that will enable fusion of external information and provide **interoperability** between the involved units for reconstruction and recovery planning to support their **cooperation** based on reliable data.

3.4. RECONASS user types

As the RECONASS system consists of such different sub systems and will be used during the regular usage of the building as well as during the response and recovery phase after damaging events diverse users will be confronted with the RECONASS system. Consequently the following user types were defined:

A. Governmental Emergency / Disaster Response Organisations

B. Non-Governmental Emergency / Disaster Response Organisations

C. Public Operators of Critical Buildings

D. Private Operators of Critical Buildings

E. Organisations involved in the development of remote sensing based damage maps

F. Organisations involved in synoptic damage prediction based on acceleration measurements, insurance companies, etc.

With the help of these user types, the relevant (or respective) user requirements (see section 3.8) and the user group members (see section 3.5) are classified. But still the users assigned to one user group differ in training and their fields of activity. For instance the user belonging to user type A – “Governmental Emergency / Disaster Response Organisations” may be an engineer who is trained to assess the building damage state or an emergency shelter specialist.

3.5. The user group

To organise the first user meeting end of March, 2014, users that were already in contact with the RECONASS consortium partners were contacted to establish the user group, join the user meetings and answer the questionnaires. The personal contacts helped to receive a good and fast feedback (see Table 10). Based on the web presence of the RECONASS project and already established contacts, further users will be sought to complete the user group of the project.

Table 10: Member organisations of the RECONASS End-user group (March 2014)

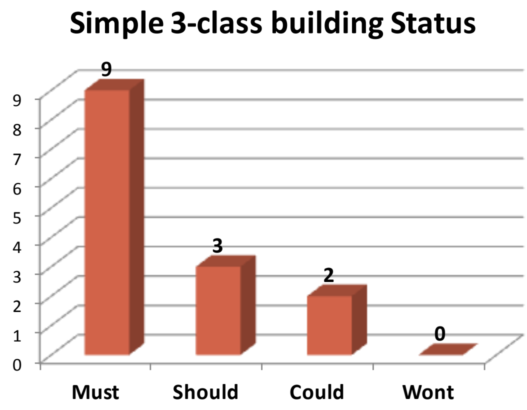
Country	Abbreviation	English Name	User type
Austria	SARUV	Regional Firebrigade Association Vorarlberg	A Governmental Emergency / Disaster Response Organization
Belgium		State Fire Service Gent / Belgium	A Governmental Emergency / Disaster Response Organization
Cyprus		Cyprus Civil Defence Commissioner. at Cyprus Civil Defence	C Public Operator of Critical Buildings
EU	DG ECHO B/1	Emergency Response, Directorate-general Humanitarian Aid and Civil Protection - ECHO	A Governmental Emergency / Disaster Response Organization
France	DGSCGC	General Directorate for Civil Protection and Crisis Management	A Governmental Emergency / Disaster Response Organization
Germany	BMUB	Federal Ministry for the Enviroment Nature Conservation, Building and Nuclear Safety	C Public Operator of Critical Buildings
Germany	THW / SEEBA	Rapid deployment search and rescue unit THW	A Governmental Emergency / Disaster Response Organization
Germany	DB	German Railway	D Private Operators of Critical Buildings
Germany	DLR-ZKI	Center for Satellite Based Crisis Information (ZKI) at DLR	E Develops / Processes remote sensing based damage maps or delivers data for damage maps
Germany	GFZ	German Research Centre for Geosciences	F Organizations involved in synoptic seismic damage prediction based on acceleration measurements, insurance companies, etc.
Germany		State Capital Düsseldorf	C Public Operator of Critical Buildings
Greece	EPPO	Earthquake Planning and Protection Organisation	F Organizations involved in synoptic seismic damage prediction based on acceleration measurements, insurance companies, etc.
Israel	MDA	Magen David Adom Israel	B Non-Governmental Emergency / Disaster Response Organization
Italy	ITHACA	Univ. of Torino / ITHACA - Information Technology for Humanitarian Assistance,	E Develops / Processes remote sensing based damage maps or delivers data for damage maps

		Cooperation and Action	
Italy		White Cross South Tyrol (Relief Organisation)	B Non-Governmental Emergency / Disaster Response Organization
Italy	DICEA	University La Sapienza	E Develops / Processes remote sensing based damage maps or delivers data for damage maps
Italy		Univ. of Pavia	A Governmental Emergency / Disaster Response Organization
Italy	DPC	Department of Civil Protection Italy	C Public Operator of Critical Buildings
Poland	KGPSP	National Headquarters of the State Fire Service of Poland	A Governmental Emergency / Disaster Response Organization
Romania	GIES / IGSU	General Inspectorate for Emergency Situations	A Governmental Emergency / Disaster Response Organization
Sweden		Swedish Fortifications Agency	A Governmental Emergency / Disaster Response Organization
Sweden		Jernhusen	D Private Operators of Critical Buildings
Turkey	GEA	GEA Search and Rescue	B Non-Governmental Emergency / Disaster Response Organization

3.6. First evaluation of the questionnaires

Until the end user workshop end of March, 2014, 19 questionnaires were sent back. First results are presented with aid of the following figures (Figure 14 to Figure 16). These figures are based on the 14 evaluated questionnaires for governmental and non-governmental response teams (user type A and B).

Figure 14, on the left side, shows the results for the question: “Do you need a **simple post-event building status** of the monitored building such as usable, partially usable and unusable?” The results clearly point out, that this is needed. In contrast the question “**Do you need:** the actual **measured data** such as stresses and plastic deformations?” Figure 14 (on the right side) shows, that here the opinions differ widely; presumably depending on the different tasks the users of this group have to perform.



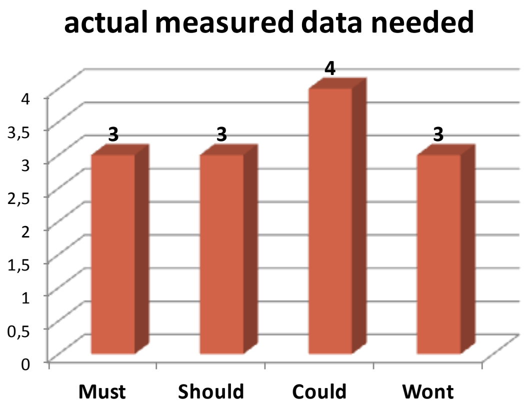


Figure 14: Disaster response organisations: required building status classification (left) and need of actual measured data (right)

The question “What would be the specific losses and needs to be identified by the PCCDN?” shows in the group of disaster responders (Figure 15) that the assessment of damages and the needs for shoring and shelter are preferred to assessed repair costs and manpower for repair and reconstruction. But this image may change, when the other user groups will be analysed.

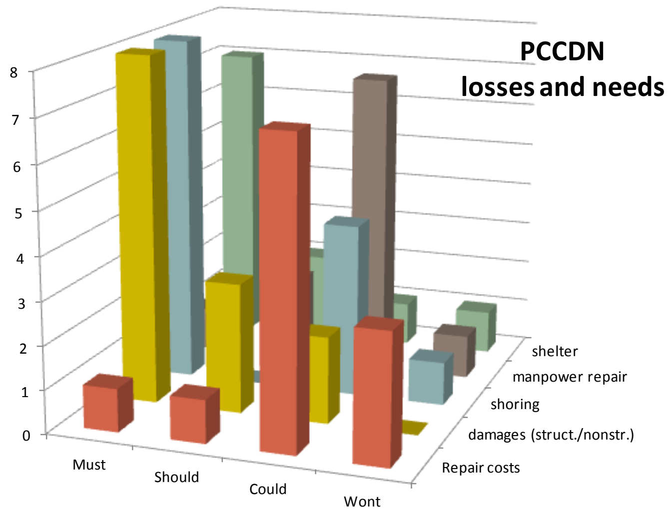


Figure 15: Disaster response organisations: required building status PCCDN results

The disaster responders answer the question “How do you want to receive the data?” related to the sensor network and monitoring system that the data transfer via the internet is commonly preferred (see Figure 16). A hard copy print out at the building is needed much less.

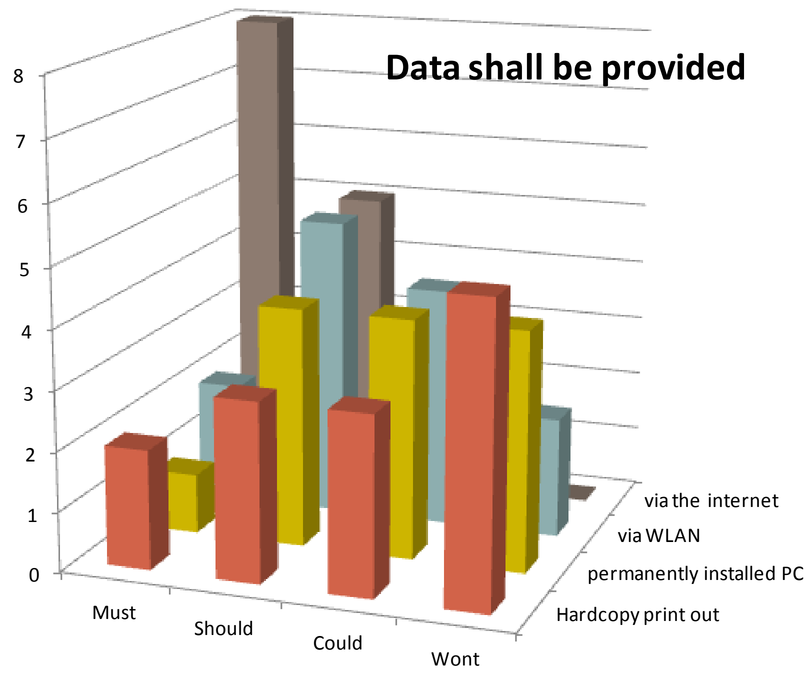


Figure 16: Disaster response organisations: required data transfer technology

These first results will be completed with the evaluation of further questionnaire feedback. Especially the user types C-F (see section 3.4) need to be examined further.

3.7. User requirements types

The user requirements are distinguished between functional (FR) and non functional (NFR) after (Sommerville 2011):

1. Functional requirements (FR): These are statements of services the system should provide, how the system should react to particular inputs and how the system should behave in particular situations. In some cases, the functional requirements may also explicitly state what the system should not do.

2. Non-functional requirements (NFR): These are constraints on the services or functions offered by the system. They include timing constraints, constraints on the development process and standards. Non-functional requirements often apply to the system as a whole. They do not usually just apply to individual system features or services.

The preliminary user requirements table (see Annex, Preliminary user Requirements) includes the column “Req. Type”, which refers to this classification. A more detailed classification of non-functional requirements including sub-types such as “interoperability”, “usability”, performance and “availability” will be used for the final requirements specification. For functional requirements the sub-classification will include the application area such as “data and information” or “communication”.

The ISO/IEC 25010 standard classifies software quality and is used to classify non-functional requirements. It will be used for a more detailed classification of the final user requirements.

In reality, the distinction between different types of requirement is not as clear-cut as these simple definitions suggest. A user requirement concerned with security, such as a statement limiting access to authorized users, may appear to be a non-functional requirement. However, when developed in more detail, this requirement may generate other requirements that are clearly functional, such as the need to include user authentication facilities in the system (56). Especially the interface requirements – both user interfaces and interfaces with other systems - are here defined as non-functional requirements because the interfaces describe how the system behaves.

3.8. Preliminary user requirements

The preliminary user requirements base on the state of the art analysis (section 1) and the analysis of the disaster events (section 2). Further input of the RECONASS partners and of experienced THW members led to the questionnaire to accomplish, specify and consolidate the user requirements.

The first results of the user group were used to elaborate the preliminary user requirements. This resulted in the preliminary user requirements table with 102 user requirements. The table is basis of the following workshop on user requirements and the document on final user requirements. The classification system used in the table is defined in the previous sections

Table 11: Preliminary user requirements

Nr.	User requirement	Value	Description/comments/ links	Group	RECONASS Sub system	User type	Req. Type	MSCW
1	The sensor network/monitoring system shall be easy to use by architects and engineers with a training of max:	1 week			1	CDF	NFR	M
2	The sensor network shall be easily started by an untrained user				1	CD	NFR	S
3	The system shall tolerate power break down for some hours Pass/Fail Statement: At least:	>24 h			1,2,3		NFR	M
4	The system must start automatically after power break down				1,2,3		FR	M
5	The sensor network/monitoring system shall provide different goals or types for the instrumentation e.g. expected maximum losses, necessary precision of the damage estimation				1	CD	NFR	S
6	The sensor network/monitoring system shall support differnet user types such as engineers and untrained personnel to assess the damages				1	ABC D	NFR	M
7	The monitoring system shall have a GUI to support the planning of the building instrumentation				1	CD	NFR	S
8	The system shall have a GUI that shows the place of an damaged sensor and the				1	CD	NFR	S

	maintenance measures necessary to ensure functionality							
9	The system parts shall provide easy to access failure status and maintenance information				1	CD	NFR	S
10	The damage assessment sub-system is reliable because human lifes depend on it				1.3	ABC DF	NFR	M
11	The damage assessment sub-system shall assess information in near real time	<30 min			1.3	ABC DF	NFR	M
12	The damage assessment sub-system shall assess structural damages				1.3	ABC DF	FR	M
13	The damage assessment sub-system shall assess repair needs				1.3	CDF	FR	M
14	The damage assessment sub-system shall assess generated debris				1.3	ABC DF	FR	M
15	The damage assessment sub-system shall assess building functionality				1.3	ABC DF	FR	M
16	The system shall be designed for reinforced concrete buildings				1,2,3	ABC DEF	NFR	M
17	The life expectancy of the sensor network/monitoring system shall be	>25 years			1	CD	NFR	M
18	Battery powered sensor and communication units shall have battery change intervals of	>2 years			1	CD	NFR	M
19	Sensor units are small enough to be integrated into the building structure during construction				1	CD	NFR	M
20	Maximum sensor unit size shall be	25x50x100 mm			1	CD	NFR	M
21	Parts of the sensor network/monitoring system shall be allowed to be connected by cables for power supply and communication				1	CD	NFR	M
22	If cables are used, cable damages shall be detected and reported				1	CD	NFR	M
23	If cables are used, the units are functional (measurement and communication) for:	>48 h			1	CD	NFR	M

24	Conformity with the relevant regulations shall be reached and declaredEC				1,2,3	ABC DEF	NFR	M
25	The system shall deliver a simple post-event building status of the monitored building with the status usable, partially usable and unusable				1,2,3	ABC DEF	FR	M
26	The system shall provide an interface to read out actual measured data				1	ABC D	NFR	S
27	The system shall show the position of the sensors and the measured events in a 3D model				1	ABC D	FR	S
28	The system shall provide aerial photos of the undamaged structure				2	ABC DEF	FR	S
29	The system shall provide aerial vertical imagery of the damaged structure				2	ABC DEF	FR	S
30	The system shall provide oblique imagey of the damaged structure				2	ABC DEF	FR	S
31	The system shall provide detailed imagery of details of the damaged structure				2	ABC D	FR	S
32	The system shall provide thermal imagery to detect persons				2	AB	FR	C
33	The system shall priovide damage maps with a higher accuracy than the actual standard				2	ABC DEF	FR	M
34	The system shall provide GIS-ready data				1,2,3	ABC DEF	NFR	S
35	The system shall generate reports using the pdf format				1,2,3	ABC DEF	NFR	S
36	The system shall provide hard copy print-outs				1	ABC D	NFR	S
37	The system shall include a permantly installed PC / monitor at the building to view data and calculation results				1	ABC D	NFR	S
38	The system shall deliver data and results via WLAN				1.2	ABC D	NFR	S
39	The system shall allow to monitor measured or calculated data during an intervention to enhance safety				1	AB	FR	S

40	The system must be designed for different operators	building operator, fast response personnel, architects and engineers, maintenance personnel			1	ABC D	NFR	M
41	The monitoring system for response personnel must be reliable because otherwise human losses will occur				1	AB	NFR	M
42	The result of the damage assessment sub system in regarding the further usability of the building must be reliable because otherwise human losses may occur				1	CDF	NFR	M
43	The Post Crisis Needs Assessment Tool (PCCDN) shall assess repair costs for affected areas				3	ABC DEF	FR	S
44	The Post Crisis Needs Assessment Tool (PCCDN) shall assess structural damages for affected areas				3	ABC DEF	FR	S
45	The Post Crisis Needs Assessment Tool (PCCDN) shall assess non-structural damages for affected areas				3	ABC DEF	FR	S
46	The Post Crisis Needs Assessment Tool (PCCDN) shall assess shoring and demolition needs for affected areas				3	ABC DEF	FR	S
47	The Post Crisis Needs Assessment Tool (PCCDN) shall assess needed manpower for repair and reconstruction for affected areas				3	ABC DEF	FR	S
48	The Post Crisis Needs Assessment Tool (PCCDN) shall assess needs of shelter, camps and housing for affected areas				3	ABC DEF	FR	S
49	The Post Crisis Needs Assessment Tool (PCCDN) shall provide detailed maps with information for single buildings for affected areas				3	ABC DEF	FR	S
50	The Post Crisis Needs Assessment Tool (PCCDN) shall provide overview maps for affected areas, information summarized for:	100x100 m			3	ABC DEF	FR	S
51	The Post Crisis Needs Assessment Tool (PCCDN) shall assess damages to	roads, water supply, electricity			3	ABC DEF	FR	C

	lifelines							
52	The PCCDN overview maps shall be available after:	12h			3	ABC DEF	NFR	S
53	The PCCDN detailed maps shall be available after:	24h			3	ABC DEF	NFR	S
54	The system shall be able to exchange data with:	open source interface			3	ABC DEF	NFR	M
55	Building damages shall be cathegorized additionally after EMS98 scale				1.3	ABC DEF	NFR	S
56	The monitoring system shall provide an alarm function				1	ABC D	FR	S
57	The data exchange shall not be accessed by others				1.3	ABC DEF	NFR	S
58	The data to be exchanged must be classified in different security levels				1,2,3	ABC DEF	NFR	M
59	The system shall support building maintenance indicating the needed type of maintenance				1	CD	FR	C
60	If installed after construction: Prior damages or deterioration shall be determined by the system				1	CD	FR	C
61	The sensor network/monitoring system shall be connected with other monitoring systems. Which:	Fire detecting installation			1	ABC D	NFR	C
62	The GUI shall be user friendly and easy to understand				1,2,3	ABC DEF	NFR	M
63	The trainig for the different sub systems and users shall not exceed:		different numbers for different users and sub systems		1,2,3	ABC DEF	NFR	M
64	Accuracy of non line of sight measurement		Positioning and distance measurement	1.1	1	ABC D	NFR	M
65	Resilience in multi-path environments		Positioning and distance measurement and secure communication	1.2	1	ABC D	NFR	M
66	Enhanced accuracy by comparison of pre- and post event measurements		Positioning and distance measurement	1.3	1	ABC D	NFR	M
67	Integration into the building structure and antenna design		Positioning and distance measurement and secure communication	1.4	1	ABC D	NFR	M
68	Low power consumption to enhance battery life		Positioning and distance measurement and secure communication	1.5	1	ABC D	NFR	M
69	Enhanced range in reinforced concrete buildings		Positioning and distance measurement secure communication	1.6	1	ABC D	NFR	M
70	Common framework of		Secure communication	1.7	1	ABC	NFR	M

	communication for sensor networks					D		
71	Communication gateway must be interoperable to bridge between different types of sensor networks		Secure communication	1.8	1	ABC D	NFR	M
72	fault tolerance: if sensor nodes fail, the communication system must reroute the data paths –		Secure communication	1.9	1	ABC D	NFR	M
73	Interoperability: the gateway should be capable to operate different wireless access technologies		Secure communication	1.10	1	ABC D	NFR	M
74	Measurement data must be transported secure and not be manipulated.		Secure communication	1.11	1	ABC D	NFR	M
75	Sensor data acquirement and data transmission must be fast enough to allow near real time damage assessment		Positioning and distance measurement secure communication	1.12	1	ABC D	NFR	M
76	Interoperability with GDACS must be ensured.		Post earthquake response and recovery	2.1	1,2,3	ABC DEF	NFR	M
77	Standardized interfaces for communication and data exchange with actual common data exchange platforms such as GDACS and VirtualOSOCC		Post earthquake response and recovery	2.2	1,2,3	ABC DEF	NFR	M
78	Results of comparable research projects must be monitored to ensure standardized interoperability		Post earthquake response and recovery, all RECONASS research areas	2.3	1,2,3	ABC DEF	NFR	M
79	VEBE damage assessment tool to be used for the damage simulation		Damage simulation and assessment	2.4	1.3	ABC DEF	NFR	M
80	Standardized interfaces for communication and data exchange with local damage assessment systems such as HAZUS		Damage simulation and assessment	2.5	1,2,3	ABC DEF	NFR	M
81	Structural damage assessment must consider the structures of specific buildings		Assessment of structural damages	2.6	1	ABC D	NFR	M
82	Vibration based damage assessment and strain monitoring must be combined to achieve reliable and precise results		Assessment of structural damages	2.7	1	ABC D	NFR	M
83	Sensor networks and damage assessment must		Sensor networks, and assessment of structural	2.8	1	ABC D	NFR	M

	be applicable to already existing buildings (after the construction phase)		damages					
84	Structural damage assessment based on sensor measurements enhances credibility and assessment quality		Assessment of structural damages	2.9	1	ABC D	NFR	M
85	The nonstructural elements must include unreinforced non-load bearing masonry walls		Assessment of nonstructural damages	2.10	1	ABC D	NFR	M
86	The assessment of the damages must be calculated within minutes after the event		Damage simulation and assessment	2.11	1	ABC D	NFR	M
87	The assessment of building functionality, repair needs and generated debris must be calculated within few hours		Damage and needs assessment	2.12	1.3	ABC D	NFR	M
88	Legal conditions must be fulfilled.		UAV used to generate oblique airborne imagery	3.1	2	ABE	NFR	M
89	Public opinion must tolerate the use of "drones"		UAV used to generate oblique airborne imagery	3.2	2	ABE	NFR	M
90	UAV Operators need time to reach the affected area		UAV used to generate oblique airborne imagery	3.3	2	ABE	NFR	M
91	Actual satellite data is available after hours or days		Air and space born remote sensing	3.4	2.3	ABC DEF	NFR	M
92	Oblique imagery is necessary to detect damages below roof level		Damage detection	3.5	2.3	ABC DEF	NFR	M
93	3D point clouds from the multi-perspective, oblique and high overlapping images are necessary for detailed damage assessment		Damage detection	3.6	2.3	ABC DEF	NFR	M
94	Low flying UAVs can provide high resolution imagery that is necessary for search and rescue organisations		Support for response teams	3.7	2.3	ABC D	NFR	M
95	UAVs do not put pilots at risk		UAV used to generate oblique airborne imagery	3.8	2	ABC D	NFR	M
96	Further development in terms of accuracy, reliability and use of radiometric and optic sensors is necessary		Airborne sensor technology	3.9	2	ABC DEF	NFR	M
97	Satellite and airborne information gathering must be combined to reach a high level of information quality and reliability		Damage detection	3.10	2.3	ABC DEF	NFR	M

98	Volumes of debris and collapsed buildings must be measured		Damage detection (roads and buildings), needs assessment	3.11	2.3	ABC DEF	NFR	M
99	Imagery must be used to improved the damage assessment based on sensors in buildings		Sensor networks, and assessment of structural and nonstructural damages	3.12	2.3	ABC DEF	NFR	M
100	Building sensors must be located in the images generated by UAVs		Multi sensor assessment	3.13	1.2	ABC D	NFR	M
101	Correlation between building sensor network position data and the 3D model derived from airborne imagery		Multi sensor assessment	3.14	1.2	ABC D	NFR	M
102	The possibility to extend the building sensor network with disaster/emergency relevant chemical and biological sensors has to be investigated		Sensor network extension	3.15	1,2,3	ABC DEF	NFR	M

CONCLUSIONS

The document describes the state of the art within the RECONASS research focus and the steps to retrieve the preliminary user requirements. Shortfalls and misfits as well as the necessary improvements in the field of a) accurate positioning and secure communication, b) Damage, Loss and Needs Assessment Methods for recovery and reconstruction planning and c) Synergistic Damage Assessment with Air and Space borne Remote Sensing result from the state of the art analysis. These results were used to formulate requirements.

In the field of Damage, Loss and Needs Assessment Methods for recovery and reconstruction planning, a wide range of tools to support the post disaster needs assessment process is available and each solution must fit in standards that are currently developed under the framework of the United Nations and the European Community. There is an urgent need of technical solutions combining the results of damage simulation and assessment, damage assessment based on measurements in affected buildings, aerial imagery based damage assessment and needs assessment based on observations. Additionally, in the field of damage assessment for non-structural elements of a building exposed to fire, explosions or seismic load, there is a need for highly specialised technical solutions.

A first damage assessment based on inventory and event data is adequately provided by many tools such as HAZUS or GDACS. The second step to generate a rough overview over the observed damages in complex situations from the observations of different stakeholders takes usually too much time, e.g. for the Haiti earthquake 19 days to produce a first map indicating all damaged buildings. In order to coordinate the first disaster response activities, maps indicating damages and urgent response needs should be available in principle after 24 to 48 hours. This gap between the first automatic assessments and the observation based information can be filled by recalibrating damage and loss assessments with the observations of occurred damages.

Continually, the humanitarian community is claiming a more harmonised approach to needs assessment procedures (19), (20). Currently, many organisations and projects aim at standardising post disaster needs assessment processes; A very challenging task because of the diversity of organisations involved, as e.g. assessment and recovery organisations, governmental and non-governmental organisations, national and international ones, each of them with different objectives and assessment methods due to their particular experience in their respective fields of activity.

Technical solutions for faster and more reliable post disaster needs assessment procedures are urgently needed. In this respect, RECONASS is a further important player in this field, concentrating on technical solutions aiming at filling this gap described above. RECONASS has to follow the standards developed under the framework of the United Nations and the European Community to contribute to the common effort in response and recovery.

The deployment of UAVs is still an innovation in the field of emergency response. Legal aspects and public opinion make this development even more difficult. But only with a broad use of all available data especially when comparing and combining information from different sources, a fast and reliable understanding of the damage situation will be possible. In addition to the determination of the overall damage state of a building, responders might more often be interested in detailed imagery of sources of falling hazards as well as of openings to access victims or indicators of damages such as cracks or displacements. Due to this reason flights at different times depending on the tasks and undertakings that have to be performed could be necessary.

In the field of local positioning systems, a high positioning accuracy and coverage need to be reached within a building structure made of reinforced concrete. Additionally the system needs to be embedded in the building structure taking into account power consumption, maintenance and reliability.

The disaster events in Haiti 2010 and in the region of L'Aquila/Italy 2009 as well as the Oklahoma City bombing of the Murrah Building 1995 were analysed focussing on the lessons learnt related to assessment tools. For the response activities at single partly collapsed buildings, it was observed, that it is very time consuming and dangerous to assess the stability of the structure and to decide about further measures such as shoring or evacuation. Some points of interest to assess the stability may be covered under debris, others are at high positions and can only be examined from above using a fire service turntable ladder or a helicopter or an UAV.

Even if it is possible to observe the structure, the actual forces and stresses within the structure cannot be assessed exactly in complex situations that mostly derive from partial collapses. During the rescue activities, debris and damaged parts of the building have to be moved. This leads to changes and sometimes instability of the static system. Therefore, it is necessary to constantly monitor the stresses and movements of relevant parts within the structure in order to secure the rescue activities. Moreover, in order to increase the chances of rescue on the one hand and on the other hand to reduce additional risk for rescuers themselves, it is very important to accelerate the process of the structural assessment as far as possible.

Reliable and comprehensive end-user requirements are crucial for the development of the RECONASS system. Preliminary requirements are therefore the prerequisites for the first RECONASS end user workshop (deliverable 1.2) and the final RECONASS user requirements (deliverable 1.3). In order to gather more input, a specialised user group was initially established and a RECONASS end-user questionnaire adapted to the different background of different user types was specially designed. First results from this user group were encompassed into the preliminary user requirements. The final quantifications, weightings and further specifications of the user requirements will be reached based on the RECONASS end user workshop (deliverable 1.2).

In order to better understand and to assess the complexity of the RECONASS system, three sub systems are established. These sub systems can be shortly described as 1) a sensor network for critical buildings. 2) the calibration of the damage and needs assessment using airborne imagery and 3) a post crisis needs assessment tool. The users of such a system are as diverse as the system itself. Therefore, six user types were defined consisting of planners and operators of buildings and of the technical infrastructure, members of emergency and disaster response organisations, providers of damage maps, insurers and further stakeholders.

But even the users assigned to one user group differ depending on their fields of activity. For instance: Within the user group belonging to user type “Governmental Emergency / Disaster Response Organisations” may be an engineer who is trained to assess the building damage state as well as an emergency shelter specialist.

The work on this deliverable can be seen as an indicative collection of major examples of existing methods and procedures, being the basis for the continuing work within RECONASS and at the same time a project livelong living process. This is why the user group will accompany the RECONASS project until the end in order to constantly evaluate and further contribute to the process. The next steps will be the RECONASS user meeting (deliverable 1.2), further extension of the user group and further dissemination of the questionnaire. The final user requirements (deliverable 1.3) are basically needed for the RECONASS system specification.

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ANNEXES

Questionnaire 1

User Requirements

Questionnaire

RECONASS

Reconstruction and REcovery Planning:

Rapid and Continuously Updated COnstruction Damage and Related Needs ASSessment

WP1: User Requirements and System Architecture

Questionnaire

Governmental and Non-Governmental Emergency / Disaster Response Organizations

A. Introduction

RECONASS is a project co-funded by the European Commission under FP7 (No 312718) that started in December 2013 with duration of 42 months. Further details can be found at http://www.reconass.eu.

In order to support the development of the RECONASS system during the project term, three user meetings will be organized.

Completing the questionnaire will take approximately **15 minutes** of your time.

Please press "**submit**" after completion **or if not possible** please send the questionnaire until February 27th, 2014.

by email (markus@baufb.de), fax (Fax: +49 228 940 1520) or mail to: Technisches Hilfswerk, Referat E1 "RECONASS", Provinzialstr. 93, D- 53127 Bonn, Germany

THANK YOU for supporting RECONASS!

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Technisches Hilfswerk

User Requirements

Questionnaire

B. The RECONASS System

The RECONASS System is mainly designed for earthquake events, explosions and fires and consists of

1: A **sensor network** to be integrated in **critical buildings of** such as hospitals, fire stations or important transportation hubs. It includes an evaluation unit to assess the structural damages (with and without collapse), direct economic loss and needs of repair. Sensor measurements and damage assessments will reach the base station at real time, so, e.g. the Department of Health will know almost immediately after an earthquake if monitored hospitals are safe.

2. **Calibration of damage and needs assessment maps** derived e.g. from satellite or aerial images using the detailed assessments of monitored buildings and additional **multi view oblique airborne imagery acquired by an unmanned aerial vehicle (UAV)**, provided with a likely time delay of 1-2 days due to equipment deployment to the incident site.

3. A **post-crisis needs assessment tool** in regards to construction damage and related needs (PCCDN) that will enable fusion of external information and provide **interoperability** between the involved units for reconstruction and recovery planning to support their **cooperation** based on reliable data.

User types of the RECONASS system will be:

A. **Governmental** Emergency / **Disaster Response** Organizations
B. **Non-Governmental** Emergency / **Disaster Response** Organizations
C. **Public Operators** of Critical **Buildings**
D. **Private Operators** of Critical **Buildings**
E. **Organizations** involved in the **development** of remote sensing based **damage maps**
F. Organizations involved in synoptic **damage prediction** based on acceleration measurements, **insurance companies, etc.**

C. Instructions

You can fill in the pdf document on your computer and send it back using the submit button. You can also use the printout and send it back, preferably by email. If you want to add comments, please use the comment field at the end of the document or an additional email/ sheet of paper.

Some questions use the MoSCoW requirements attempt:

M - MUST: Describes a requirement that must be satisfied in the final solution for the solution to be considered a success.

S - SHOULD: Represents a high-priority item that should be included in the solution if it is possible. This is often a critical requirement but one which can be satisfied in other ways if strictly necessary.

C - COULD: Describes a requirement which is considered desirable but not necessary. This will be included if time and resources permit.

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User Requirements

Questionnaire

W - WONT: Represents a requirement that stakeholders have agreed will not be implemented in a given release, but may be considered for the future. (note: occasionally the word "Would" is substituted for "Won't" to give a clearer understanding of this choice)

If you are not sure with your answer you can skip it and go ahead to the next question.

User Requirements

Questionnaire

D. Questions

1	Organization				
1.1	What is the **official name** of your organization?				
1.2	If different: **English name** of your Organization:				
1.3	**Responsible person**/ questionnaire filled in by:				
1.4	Your **Email** address:				
1.5	**Country** your organization is situated in:				
1.6	Is your organization informed about or works with the following **organizations or products**:				
		Frequently	Occasionally	Known	Unknown
a	**GDACS** (Global Disaster Alert and Coordination Center)	☐	☐	☐	☐
b	**Virtual OSOCC**	☐	☐	☐	☐
c	**ECHO** (European Community Humanitarian Office)	☐	☐	☐	☐
d	**ERCC** (Emergency Response Coordination Centre)	☐	☐	☐	☐
e	**HAZUS**	☐	☐	☐	☐
f	**International Charter** Space and Major Disasters	☐	☐	☐	☐
g	**Other** relevant damage and needs assessment tools or organizations you work with:				

		Yes!	Depends	No
1.7	Are you **basically interested in participating in the RECONASS user group?**	☐	☐	☐
1.8	Would you like to be invited to a **1 day user meeting (24-03-2014)**?	☐	☐	☐
1.9	Would you prefer that the **RECONASS project covers your travel expenses**?	☐	☐	☐

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User Requirements

Questionnaire

2	Sensors in buildings: Information about single buildings				
		Must	Should	Could	Wont
2.1	Do you need a **simple post-event building status** of the monitored building such as usable, partially usable and unusable?	☐	☐	☐	☐
2.2 a	**Do you need:** the actual **measured data** such as stresses and plastic deformations?	☐	☐	☐	☐
b	**detailed results** of the **damage and loss assessment**?	☐	☐	☐	☐
c	information about the **remaining load capacity** of the building and its elements?	☐	☐	☐	☐
d	a **3D building illustration** visualizing the damage data?	☐	☐	☐	☐
e	actual **aerial photos** of the damages taken by the UAV?	☐	☐	☐	☐
2.3	**How do you want to receive the data (2.2)?**	**Must**	**Should**	**Could**	**Wont**
a	**Raw sensor data** (e.g. temperatures , peak accelerations, strains for your own software)	☐	☐	☐	☐
b	**3D model** data	☐	☐	☐	☐
c	**GIS** ready data	☐	☐	☐	☐
d	**Pdf** documents	☐	☐	☐	☐
e	Hardcopy **print-out**	☐	☐	☐	☐
f	Data and results on a **permanently installed PC** / monitor at the building	☐	☐	☐	☐
g	Data and results via **WLAN**	☐	☐	☐	☐
h	Data and results via the **internet**	☐	☐	☐	☐
i	**Other** data transfer: ________________________________	☐	☐	☐	☐
2.4	Do you need a **specific monitoring function** about the building state **during your intervention**?	☐	☐	☐	☐
2.5	Do you need an **alarm** (acoustic, light,..)?	☐	☐	☐	☐
	... minutes after the event:	**5'**	**20'**	**60'**	**later**
2.6	**When** do you need this information (2.1 -3)?	☐	☐	☐	☐
	... hours after the event:	**6 h**	**12 h**	**24 h**	**48 h**
2.7	I accept **receiving aerial photos** later:	☐	☐	☐	☐
2.8	How much time could you or your staff invest in **training** to use the system?	**1 h** ☐	**1 day** ☐	**1 week** ☐	**more** ☐
2.9	**Who** should **operate the system** (e.g. building owner, governm. organization (which?), non-profit association)?				
2.10	**Comments** about sensors in buildings, Information about single buildings:				

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User Requirements

Questionnaire

3	Post Crisis Needs Assessment Tool (PCCDN)				
3.1	**What would be your reasons to use a PCCDN?** To identify **losses and needs**…	**Must**	**Should**	**Could**	**Wont**
a	.. in **single buildings**.	☐	☐	☐	☐
b	.. in several **buildings equipped with sensors.**	☐	☐	☐	☐
c	.. an **affected area.**	☐	☐	☐	☐
d	Other: ________________________________	☐	☐	☐	☐
3.2	**What would be the specific losses and needs to be identified?**	**Must**	**Should**	**Could**	**Wont**
a	**Repair costs**	☐	☐	☐	☐
b	**Structural and nonstructural** damages	☐	☐	☐	☐
c	**Shoring** or demolition needs	☐	☐	☐	☐
d	Needed **manpower** for repair or reconstruction	☐	☐	☐	☐
	Need of **shelter**, camps, housing	☐	☐	☐	☐
e	**Detailed maps** (information for single buildings) of the whole affected area in case of a disaster	☐	☐	☐	☐
f	**Overview maps**, information summarized for blocks of 100m x 100m	☐	☐	☐	☐
d	Damages to **lifelines** like roads, water supply, electricity, and needs	☐	☐	☐	☐
d	Human losses, needs for **medical** treatment	☐	☐	☐	☐
h	Other: ________________________________	☐	☐	☐	☐
3.3	I need to **receive the results** of the PCCDN **via the internet**.	☐	☐	☐	☐
3.4	after the event:	**20'**	**60'**	**3h**	**6 h**
	When do you need maps with **detailed information for large areas** and not only for single buildings**?**	☐	☐	☐	☐
		☐	☐	☐	☐
	after the event:	**12 h**	**24 h**	**48 h**	**later**
3.5		**1 h**	**1 day**	**1 week**	**more**
	How much time could you or your staff invest in **training** to use the system?	☐	☐	☐	☐
3.6	**Who should operate the system** (e.g. building owner, governmental organization (which?), non-profit association…):				
3.7	**Comments about Post Crisis Needs Assessment Tool (PCCDN):**				

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SEVENTH FRAMEWORK PROGRAMME

User Requirements

Questionnaire

Programme funded by the EUROPEAN UNION

4	General Requirements				
		Must	Should	Could	Wont
4.1	Is it necessary, that the system can **exchange data** with other systems?	☐	☐	☐	☐
4.2	What would be the systems you would intend to exchange data with?				
		Must	Should	Could	Wont
4.3 a	In case of a major disaster: Do you need **damage information per building** for **all** buildings **in the affected area**, indicating in **5 steps** from "minor damage" to "completely destroyed"	☐	☐	☐	☐
b	Do you need **more detailed** information than 5 steps **for all buildings**?	☐	☐	☐	☐
4.4	Is it necessary, that the system gives **alarm** when **not working properly**?	☐	☐	☐	☐
4.5	**Security:** Is it necessary, that the data exchanged cannot be accessed by others?	☐	☐	☐	☐
4.6	after the event:	**30'**	**2 h**	**8 h**	**24 h**
	How long must the system work after **power breakdown**?	☐	☐	☐	☐
		☐	☐	☐	☐
	after the event:	**3 days**	**7 days**	**3 weeks**	**more**
5	**Additional requirements from your point of view**				
		Must	Should	Could	Wont
5.1		☐	☐	☐	☐
5.2		☐	☐	☐	☐
5.3		☐	☐	☐	☐
5.4		☐	☐	☐	☐
5.5	**General comments:**				

THANK YOU!

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Questionnaire 2

User Requirements

Questionnaire

RECONASS

Reconstruction and REcovery Planning:

Rapid and Continuously Updated COnstruction Damage and Related Needs ASSessment

WP1: User Requirements and System Architecture

Questionnaire

Public and Private Operators of Critical Buildings

A. Introduction

RECONASS is a project co-funded by the European Commission under FP7 (No 312718) that started in December 2013 with duration of 42 months. Further details can be found at http://www.reconass.eu.

In order to support the development of the RECONASS system during the project term, three user meetings will be organized.

Completing the questionnaire will take approximately **15 minutes** of your time.

Please press "**submit**" after completion **or if not possible** please send the questionnaire

until February 27th, 2014

by email (markus@baufb.de), fax (Fax: +49 228 940 1520) or mail to: Technisches Hilfswerk, Referat E1 "RECONASS", Provinzialstr. 93, D- 53127 Bonn, Germany

THANK YOU for supporting RECONASS!

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User Requirements

Questionnaire

B. The RECONASS System

The RECONASS System is mainly designed for earthquake events, explosions and fires and consists of

1: A **sensor network** to be integrated in **critical buildings of** such as hospitals, fire stations or important transportation hubs. It includes an evaluation unit to assess the structural damages (with and without collapse), direct economic loss and needs of repair. Sensor measurements and damage assessments will reach the base station at real time, so, e.g. the Department of Health will know almost immediately after an earthquake if monitored hospitals are safe.

2. **Calibration of damage and needs assessment maps** derived e.g. from satellite or aerial images using the detailed assessments of monitored buildings and additional **multi view oblique airborne imagery acquired by an unmanned aerial vehicle (UAV)**, provided with a likely time delay of 1-2 days due to equipment deployment to the incident site.

3. A **post-crisis needs assessment tool** in regards to construction damage and related needs (PCCDN) that will enable fusion of external information and provide **interoperability** between the involved units for reconstruction and recovery planning to support their **cooperation** based on reliable data.

User types of the RECONASS system will be:

A. **Governmental** Emergency / **Disaster Response** Organizations
B. **Non-Governmental** Emergency / **Disaster Response** Organizations
C. **Public Operators** of Critical **Buildings**
D. **Private Operators** of Critical **Buildings**
E. **Organizations** involved in the **development** of remote sensing based **damage maps**
F. Organizations involved in synoptic **damage prediction** based on acceleration measurements, **insurance companies**, **etc.**

C. Instructions

You can fill in the pdf document on your computer and send it back using the submit button. You can also use the printout and send it back, preferably by email. If you want to add comments, please use the comment field at the end of the document or an additional email/ sheet of paper.

Some questions use the MoSCoW requirements attempt:

M - MUST: Describes a requirement that must be satisfied in the final solution for the solution to be considered a success.

S - SHOULD: Represents a high-priority item that should be included in the solution if it is possible. This is often a critical requirement but one which can be satisfied in other ways if strictly necessary.

C - COULD: Describes a requirement which is considered desirable but not necessary. This will be included if time and resources permit.

SEVENTH FRAMEWORK PROGRAMME

User Requirements

Questionnaire

Programme funded by the EUROPEAN UNION

W - WONT: Represents a requirement that stakeholders have agreed will not be implemented in a given release, but may be considered for the future. (note: occasionally the word "Would" is substituted for "Won't" to give a clearer understanding of this choice)

If you are not sure with your answer you can skip it and go ahead to the next question.

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User Requirements

Questionnaire

D. Questions

1	Organization				
1.1	What is the **official name** of your organization?				
1.2	If different: **English name** of your Organization:				
1.3	**Responsible person/** questionnaire filled in by:				
1.4	Your **Email** address:				
1.5	**Country** your organization is situated in:				
1.6	Is your organization informed about or works with the following **organizations or products**:				
		Frequently	Occasionally	Known	Unknown
a	**GDACS** (Global Disaster Alert and Coordination Center)	☐	☐	☐	☐
b	**Virtual OSOCC**	☐	☐	☐	☐
c	**ECHO** (European Community Humanitarian Office)	☐	☐	☐	☐
d	**ERCC** (Emergency Response Coordination Centre)	☐	☐	☐	☐
e	**HAZUS**	☐	☐	☐	☐
f	**International Charter** Space and Major Disasters	☐	☐	☐	☐
g	**Other** relevant damage and needs assessment tools or organizations you work with:				

		Yes!	Depends	No
1.7	Are you **basically interested in participating in the RECONASS user group?**	☐	☐	☐
1.8	Would you like to be invited to a **1 day user meeting (24-03-2014)**?	☐	☐	☐
1.9	Would you prefer that the **RECONASS project covers your travel expenses**?	☐	☐	☐

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User Requirements

Questionnaire

2.12	**How do you want to receive the data (2.2)?**	**Must**	**Should**	**Could**	**Wont**
a	**Raw sensor data** (e.g. temperatures , peak accelerations, strains for your own software)	☐	☐	☐	☐
b	**3D model** data	☐	☐	☐	☐
c	**GIS** ready data	☐	☐	☐	☐
d	**Pdf** documents	☐	☐	☐	☐
e	Hardcopy **print-out**	☐	☐	☐	☐
f	Data and results on a **permanently installed PC** / monitor at the building	☐	☐	☐	☐
g	Data and results via **WLAN**	☐	☐	☐	☐
h	Data and results via the **internet**	☐	☐	☐	☐
i	**Other** data transfer: ___________________________	☐	☐	☐	☐
2.13	Do you need a **specific monitoring function** about the building state **after the event** if it was damaged?	☐	☐	☐	☐
2.14	Do you need an **alarm** (acoustic, light, sms, email..)?	☐	☐	☐	☐
	… minutes after the event:	**5'**	**20'**	**60'**	**later**
2.15	**When** do you need this information (2.1 -3)?	☐	☐	☐	☐
	… hours after the event:	**6 h**	**12 h**	**24 h**	**48 h**
2.16	I accept **receiving aerial photos** later:	☐	☐	☐	☐
	months	**6**	**12**	**24**	_____
2.17	What is the minimum technical **maintenance interval** (change of batteries, cables, sensors)	☐	☐	☐	☐
2.18 a	How much **funds** would you be willing **to invest** to have such a system? **Maximum €**	**€**			
b	**Percentage** of the total investments in the building				
		1 day	**1 week**	**1 month**	**more**
2.19	How much time could you or your staff invest in **training** to use the system?	☐	☐	☐	☐
2.20	**Who** should **operate the system** (e.g. building owner, governm. organization (which?), non-profit association)?				
2.21	**Comments** about sensors in buildings, Information about single buildings:				

SEVENTH FRAMEWORK PROGRAMME

User Requirements

Questionnaire

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2	Sensors in buildings: Information about single buildings				
		Yes	No	N/A	
2.1	Do **you administer** at least one **building with sensors** to identify its damage state?	☐	☐	☐	
2.2	Do **you intend to build in** such sensors **in the future?**	☐	☐	☐	
2.3	**When** would you prefer to **install** such a system?	☐ **During construction**	☐ **Post construction**	☐ **N/A**	
2.4	How would you **install the sensors?** **Embedded** (difficult for existing buildings), **attached** or **mixed.**	embedded ☐	☐	☐	**attached** ☐
2.5	For **attached** sensors, please mark the **maximum permissible sensor size.** Length; width; thickness **[cm]**	**2.5; 2; 1.5** ☐	**5; 4; 2.5** ☐	**12, 6; 4** ☐	**18; 8; 6** ☐
2.6	For embedded sensors, please mark the **maximum permissible drill hole diameter** **[cm]**	**2** ☐	**4** ☐	**8** ☐	**12** ☐
2.7	Would it be **allowed, to …**	**Must**	**Should**	**Could**	**Wont**
a	..use **wireless technology within** the structure?	☐	☐	☐	☐
b	..use **cables to interconnect sensors**?	☐	☐	☐	☐
2.8 a	**Where** would you **install the central processing** and monitoring **unit**?				
2.9	What are/would be the **reasons to use** such a **sensor network in your building?**	**Must**	**Should**	**Could**	**Wont**
a	To identify the **need for maintenance.**	☐	☐	☐	☐
b	To identify the **need for repair.**	☐	☐	☐	☐
c	To identify damages with **collapse** or **partial collapse.**	☐	☐	☐	☐
d	To estimate **material losses** (Building and content).	☐	☐	☐	☐
e	To estimate **human losses.**	☐	☐	☐	☐
f	Other: ________________________________	☐	☐	☐	☐
		Must	**Should**	**Could**	**Wont**
2.10	Do you need a **simple post-event building status** of the monitored building such as usable, partially usable and unusable?	☐	☐	☐	☐
2.11 a	**Do you need:** the actual **measured data** such as stresses and plastic deformations?	☐	☐	☐	☐
b	**detailed** results of the **damage** and **loss** assessment?	☐	☐	☐	☐
c	information about the **remaining load capacity** of the building and its elements?	☐	☐	☐	☐
d	**3D building illustration** visualizing the damage data?	☐	☐	☐	☐
e	actual **aerial photos** of the damages taken by an UAV?	☐	☐	☐	☐

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User Requirements

Questionnaire

3	Post Crisis Needs Assessment Tool (PCCDN)				
3.1	**What would be your reasons to use a PCCDN?** To identify **losses and needs…**	**Must**	**Should**	**Could**	**Wont**
a	.. in **single buildings**.	☐	☐	☐	☐
b	.. in several **buildings equipped with sensors.**	☐	☐	☐	☐
c	.. an **affected area.**	☐	☐	☐	☐
d	Other: ______________________________	☐	☐	☐	☐
3.2	**What would be the specific losses and needs to be identified?**	**Must**	**Should**	**Could**	**Wont**
a	**Repair costs**	☐	☐	☐	☐
b	**Structural and nonstructural** damages	☐	☐	☐	☐
c	**Shoring** or demolition needs	☐	☐	☐	☐
d	Needed **manpower** for repair or reconstruction	☐	☐	☐	☐
e	Need of **shelter**, camps, housing	☐	☐	☐	☐
f	**Detailed maps** (information for single buildings) of the whole affected area in case of a disaster	☐	☐	☐	☐
g	**Overview maps**, information summarized for blocks of 100m x 100m	☐	☐	☐	☐
h	Damages to **lifelines** like roads, water supply, electricity, and needs	☐	☐	☐	☐
i	Human losses, needs for **medical** treatment	☐	☐	☐	☐
j	Other: ______________________________	☐	☐	☐	☐
3.3	I need to **receive the results** of the PCCDN **via the internet**.	☐	☐	☐	☐
3.4	after the event:	**20'**	**60'**	**3h**	**6 h**
	When do you need maps with **detailed information for large areas** and not only for single buildings**?**	☐	☐	☐	☐
		☐	☐	☐	☐
	after the event:	**12 h**	**24 h**	**48 h**	**later**
3.5	How much time could you or your staff invest in **training** to use the system?	**1 h** ☐	**1 day** ☐	**1 week** ☐	**more** ☐
3.6	**Who should operate the system** (e.g. building owner, governmental organization (which?), non-profit association…):				
3.7	**Comments about Post Crisis Needs Assessment Tool (PCCDN):**				

User Requirements

Questionnaire

4	**General Requirements**				
		Must	**Should**	**Could**	**Wont**
4.1	Is it necessary, that the system can **exchange data** with other systems?	☐	☐	☐	☐
4.2	What would be the systems you would intend to exchange data with?				
		Must	**Should**	**Could**	**Wont**
4.3 a	In case of a major disaster: Do you need **damage information per building** for **all** buildings **in the affected area**, indicating in **5 steps** from “minor damage” to “completely destroyed”	☐	☐	☐	☐
b	Do you need **more detailed** information than 5 steps **for all buildings**?	☐	☐	☐	☐
4.4	Is it necessary, that the system gives **alarm** when **not working properly**?	☐	☐	☐	☐
4.5	**Security:** Is it necessary, that the data exchanged cannot be accessed by others?	☐	☐	☐	☐
	Security: Is a **classification system** (public, restricted, …) necessary?	☐	☐	☐	☐
4.6	after the event:	**30’**	**2 h**	**8 h**	**24 h**
	How long must the system work after **power breakdown**?	☐	☐	☐	☐
		☐	☐	☐	☐
	after the event:	**3 days**	**7 days**	**3 weeks**	**more**
5	**Additional requirements from your point of view**				
		Must	**Should**	**Could**	**Wont**
5.1		☐	☐	☐	☐
5.2		☐	☐	☐	☐
5.3		☐	☐	☐	☐
5.4		☐	☐	☐	☐
5.5	**General comments:**				

THANK YOU!

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