The 2017 International Conference on
Applications of Nuclear Techniques
Crete, Greece
June 11-17, 2017

National Technical University of Athens

CERN

# EDUSAFE Project: Control System (CS) and Data Acquisition (DAQ) architecture for the radiation background monitoring of a Personnel Safety System in the ATLAS cavern

**Evangelos Gazis**
NTUA-School of Applied Mathematics and Physics Science
**Eleni Adamidi, Marie Curie Fellow**
NTUA-School of Electrical and Computing Engineering

*Institute of Accelerating Systems and Applications*

EDUSAFE

# Outline

- General View
- EDUSAFE Collaboration
- ATLAS cavern, open problems
- EDUSAFE project
  - Goals
  - Challenges
  - Results & Deliverable
- PSS Module & WPSS prototype
- Architecture of use case
- DAQ/CS operation
- Architecture of DAQ
- Augmented Reality (AR)
- Final Result
- Exploitation steps
- Conclusions

# General View

The personnel safety and augmented reality based safety architectures can be found in many domains

**Previous works:**

- **D.E. Poole and T. Ring [1989]:** presented the Daresbury **personnel safety system**. This personnel safety system designed for the **Synchrotron Radiation Source (SRS)** is a unified system covering the three accelerators of the source itself, the beam lines and the experimental stations.

- **A. Kumar et al [2009]:** presented indoor environmental **gas monitoring system** based on **digital signal processing**. This work has focused on the problem of **real time processing** of **carbon monoxide** and **carbon dioxide gases measurement** using a DSP board (TMS320C6455) and then implementing to the proposed gas monitoring system.

- **A. Pantelopoulos et al [2011]:** described a survey **on wearable sensor-based systems** for **health monitoring** and **prognosis**. An emphasis was given **to multi-parameter physiological sensing system** designs, providing reliable vital signs measurements and incorporating real-time decision support for early detection of symptoms or context awareness.

- ..many others..

# General View

## Safety and Protection Systems

**Key Parameters on performing activities in risky environments:**

- personnel **safety**
- personnel monitoring,
- **supervision** of the environment
- even more important in case to perform **complex activities** (installation or maintenance work) in the **heavy machinery** having **radioactive** elements

**The hazardous environments not user friendly in terms of:**

- frequent access
- performing regular/sudden activities
- monitoring, and supervision works, etc.

# General View

The personnel safety and augmented reality based safety architectures can be found in many domains

EDUSAFE

**Current work:**

- In our study, ATLAS experiment environment is being considered during the **maintenance** and **upgrade** of the detector.
- During the maintenance or upgrade operations, the operators are **exposed to radiations**. The ability to monitor personnel and the state of the surrounding environment in hostile environments is crucial.
- The weak point is that the **previous transmission system** was not performing sufficiently in the ATLAS environment to support **high definition real time image transmission** from the camera to the server.
- Thus it was well understood the necessity to develop:
  - a **mobile** platform (wearable),
  - **adaptable** to different environments with varying sensing and transmitting requirements,
  - **scalable** and **robust**
- The mobile platform is crucial, because it acquires **data in real time** and streams the information to the higher layers of the architecture.

So, the objective of this work is to **demonstrate** the WPSS and **update** with **AR (Augmented Reality)** based PSS system by considering previous prototype that can be applied for **real maintenance jobs** in radioactive environment

# The EDUSAFE Collaboration, http://edusafe.web.cern.ch/

EDUSAFE

The collaboration consists: HEP + Economic & Business university teams and Industrial Partners

**INSTITUTIONS**

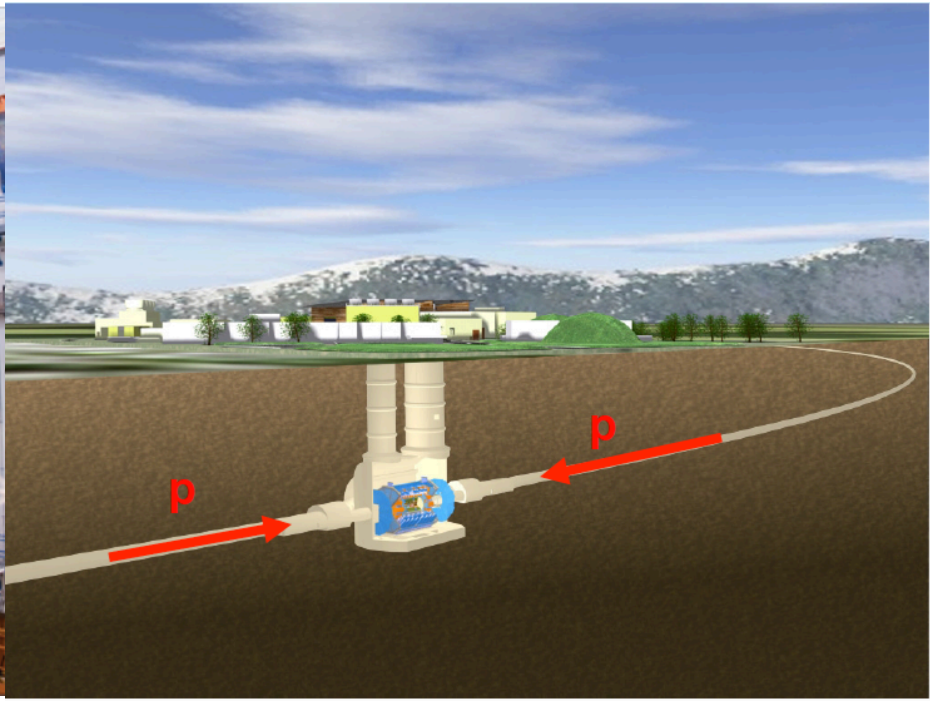
- CAEN (Caen, France)
- CERN (Geneva, Switzerland)
- EPFL (Lausanne, Switzerland)
- ROMA 2 (Rome, Italy)
- TUM (Munich, Germany)
- AUTH (Thessaloniki, Greece)
- DUTH (Xanthi, Greece)
- **IASA (Athens, Greece)**
- NKUA (Athens, Greece)
- NTUA (Athens, Greece)
- AUEB (Athens, Greece)

**INDUSTRIAL PARTNERS**

- CANBERRA (France)
- NOVOCAPTIS (Greece)
- PRISMA ELECTRONICS (Greece)

EDUSAFE

Education in advanced VR/AR Safety Systems for Maintenance in Extreme Environments

# The ATLAS Collaboration

EDUSAFE

**ATLAS the largest particle physics experiment apparatus: 22X44X11 m3**

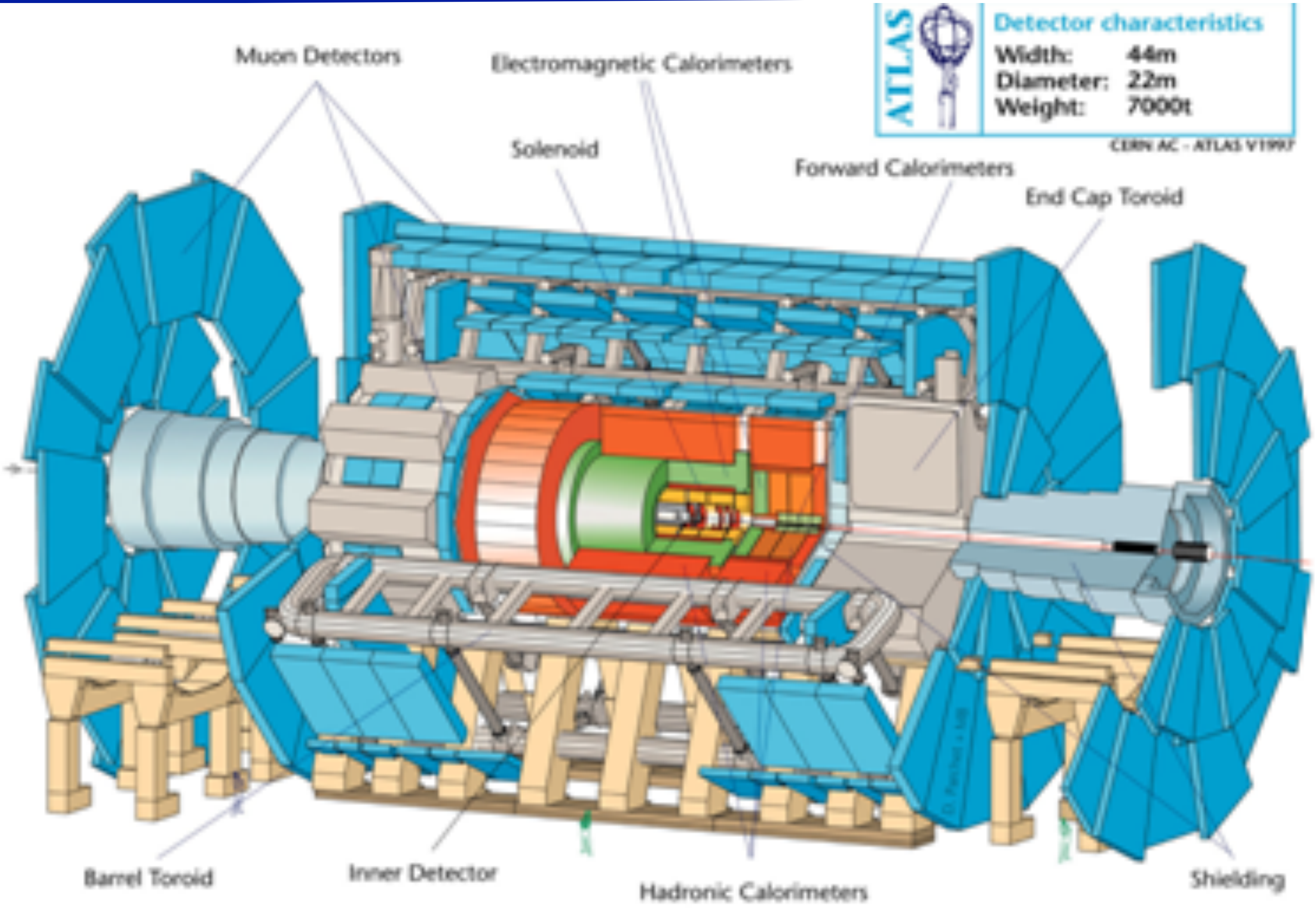
- ~2900 km of cables
- ~10 MW of electric power
- 2 – 4 Tesla magnetic field
- **Cavern** the largest artificial cave

**RESEARCHERS**

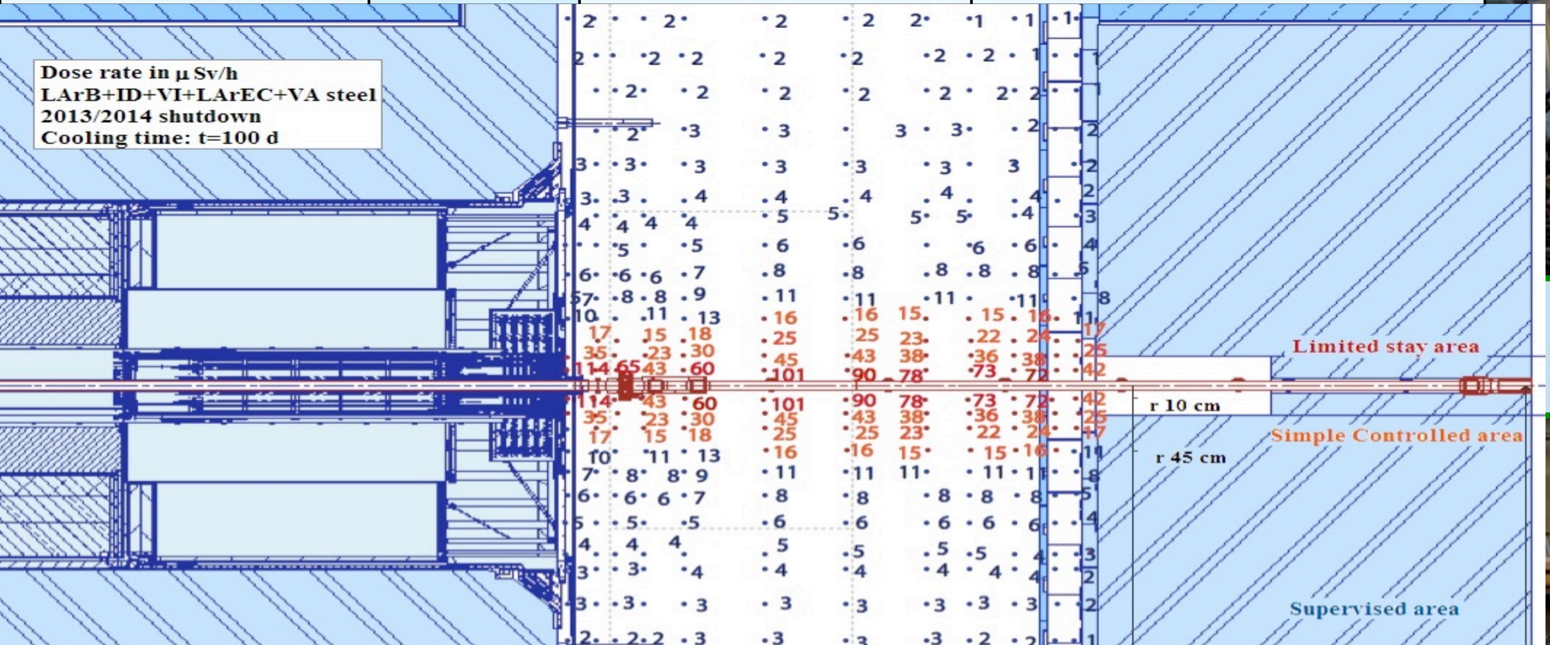
- ~3200 physicists & engineers (~1000 PhD students)
- 174 Institutes
- 38 Countries

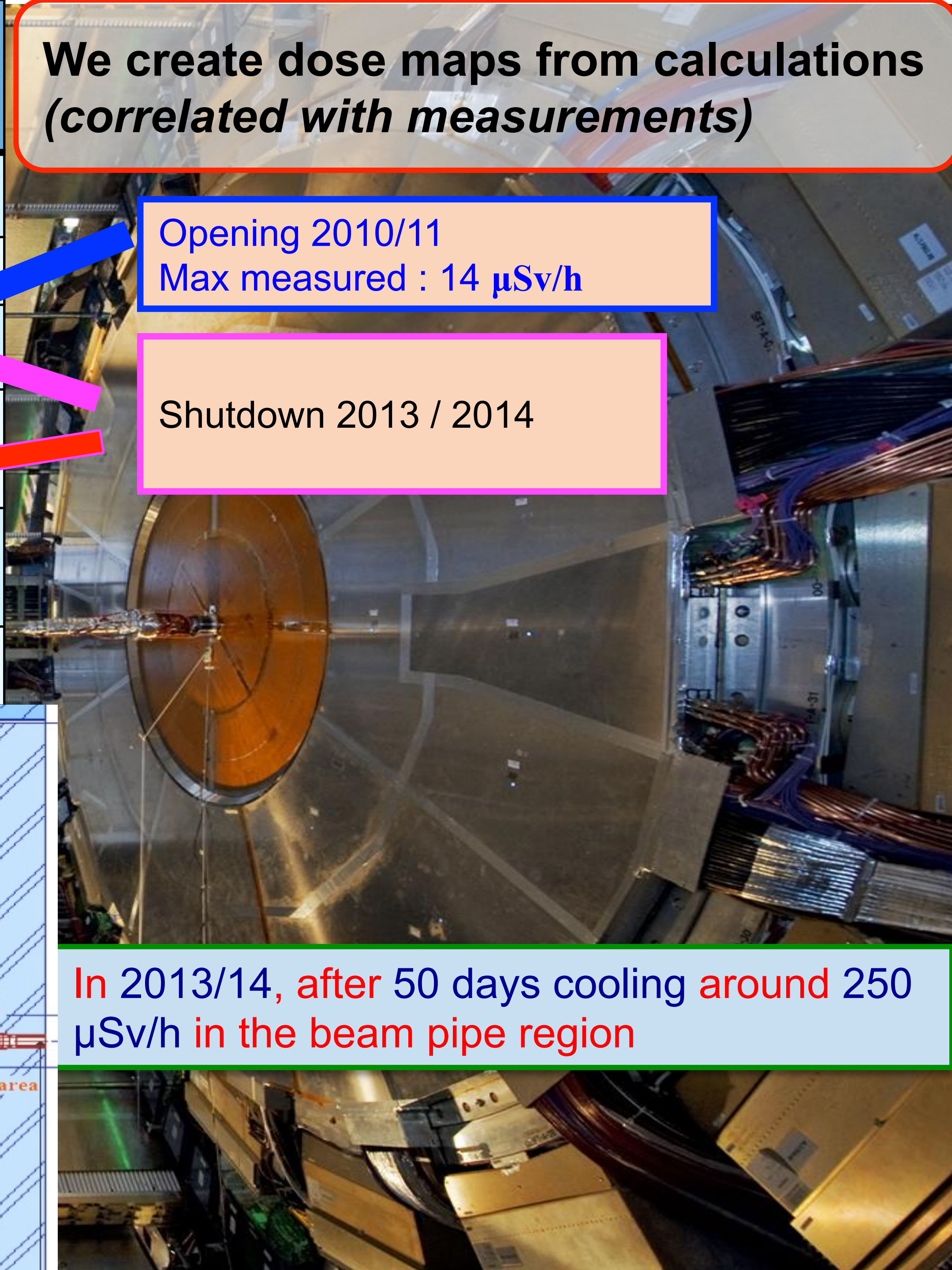
**Greek Institutes participation to the ATLAS Muon Spectrometer:**

- AUTH
- Demokritos
- NKUA
- NTUA
- UoAEGEAN
- HOU
- Tech. Inst. of Piraeus
- Tech. Inst. of East Macedonia - Thrace



| Area Classification | Dose limit | Ambient dose equivalent rate (permanent place) | Ambient dose equivalent rate (low-occupancy areas) |
|---|---|---|---|
| Non-designated area | 1 mSv/y | < 0.5 µSv/h | < 2.5 µSv/h |
| Supervised area | 6 mSv/y | < 3 µSv/h | < 15 µSv/h |
| Simple controlled area | 20 mSv/y | < 10 µSv/h | < 50 µSv/h |
| Limited stay area | | | < 2 mSv/h |
| High radiation area | | | < 100 mSv/h |
| Prohibited area | | | > 100 mSv/h |



**We create dose maps from calculations *(correlated with measurements)***

Opening 2010/11
Max measured : 14 µSv/h

Shutdown 2013 / 2014

In 2013/14, after 50 days cooling around 250 µSv/h in the beam pipe region

# The EDUSAFE Project

The collaboration consists: HEP + Economic & Business university teams and Industrial Partners

**EDUSAFE** is a 4-year Marie Curie ITN project, supported by EU, with scientific objectives:

- to demonstrate the basic architecture of the **Wireless Personnel Safety System** (**WPSS**)
- to figure out an **advanced imaging** platform for technologies:
  - Virtual Reality (**VR**)
  - Augmented Reality (**AR**), a technology, which aids in seeing a real scene with embedded data useful for human activities
- a Personnel Safety System (PSS), including **features**, **methods** and **tools**

The **output** of this project is necessary during planned and emergency **maintenance** or **upgrade operations** in the **ATLAS cavern** at CERN, where the operators are exposed to **radiations**
So, the ability to monitor **personnel** and the state of the **surrounding environment** is crucial

It can also, be implemented in **extreme** environments:

- ❑ nuclear installations
- ❑ space missions
- ❑ deep sea
- ❑ mines, etc.

# The EDUSAFE Project

The collaboration consists: HEP + Economic & Business university teams and Industrial Partners

EDUSAFE

**Goals:**

- technically advanced and combined several technologies,
- Integration of them to form a **Mobile Personnel Safety System** (**MPSS**)
- improve safety and radioprotection
- reduce errors
- decrease the time needed for scheduled or sudden interventions

**Challenges & Features:**

- real time data transmission
- instantaneous analysis of data coming from different inputs
- local intelligences in low power embedded systems
- interaction with multiple on site users
- complex interfaces
- portability and wearability

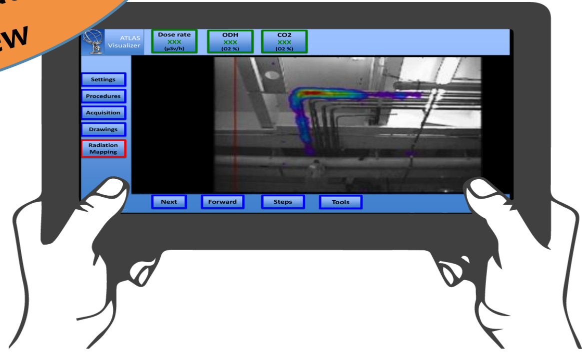
**Results:** Augmented Reality glasses + smart helmet

**EDUSAFE Supervision System:**

- allowing bi-directional communication and guiding the user
- providing information for radioprotection and other environmental purposes

**2nd example Mobile Personnel Safety System / AR glasses**

**1st example Radiation Hot Spot Localization / iPad View**



# The EDUSAFE Deliverables

The collaboration consists: HEP + Economic - Business university teams and Industrial Partners

1. General survey on the present state of the art and first design report of **algorithms**, **WRM** (Weighted Resistor Matrix) and related **interfacing protocols**
2. Study of the state of the art of **gamma radiation imaging** systems and dose calculation codes and their corresponding technologies
3. **Control** and **DAQ** system H/W – S/W architecture design report, PSS module H/W – S/W architecture design report
4. **MPSS module, CS-DAQ** prototypes developed and tested, system documentation with final performance tests, results and recommendations. Report on scalability and adaptability to different infrastructure and environmental conditions
5. New **gamma imager**, reconstruction algorithms and new fast dose calculation algorithms, including AR features performance and validation test campaign
6. Integrated **VR/AR system** prototype
7. **Final prototype**, evaluation board and starter ready for final test in **ATLAS**
8. **Validation** of data from demonstration

9. **Market study**, technological assessment and initial **business model**
10. Technological assessment and **reverse engineering potential**
11. **Market feedback** on prototype and demonstration

# The EDUSAFE Project

The collaboration consists: HEP + Economic & Business university teams and Industrial Partners

The WPSS module consists of:

- **Personnel Trans-receiving Unit** (**PTU**), hosting the communication module

- An essential **node** for propagating the data from the **cameras (video & gamma)** and **sensors** to the control system and vice versa from the control system to the HMDs (**Head Mounted Display**)

- **Safety sensors** and **Local Intelligence**, for data/video local treatment

- A very **challenging optimization** is required for the **local data processing** to produce:

    - sufficiently powerful system
    - highly reliable
    - low power consumptions
    - small size and weight
    - suitable to the workers in the most demanding environments

# The EDUSAFE Project

The collaboration consists: HEP + Economic & Business university teams and Industrial Partners

EDUSAFE

**WPSS PROTOTYPE DESCRIPTIONS**

1. **User Case Analysis**

The system users can be categorized in to **four** groups:

- Technician is the user with the PTU and the helmet with the γ-camera & video camera
- Supervisor receives all the latest measurements in real time and will communicate through audio and camera with the technician
- Administrator has rights to change parameters and maintenance the PTUs and the server side programs like the data acquisition
- Support user has access to get the system's data through third party applications for further analysis

**2. Operation indications**

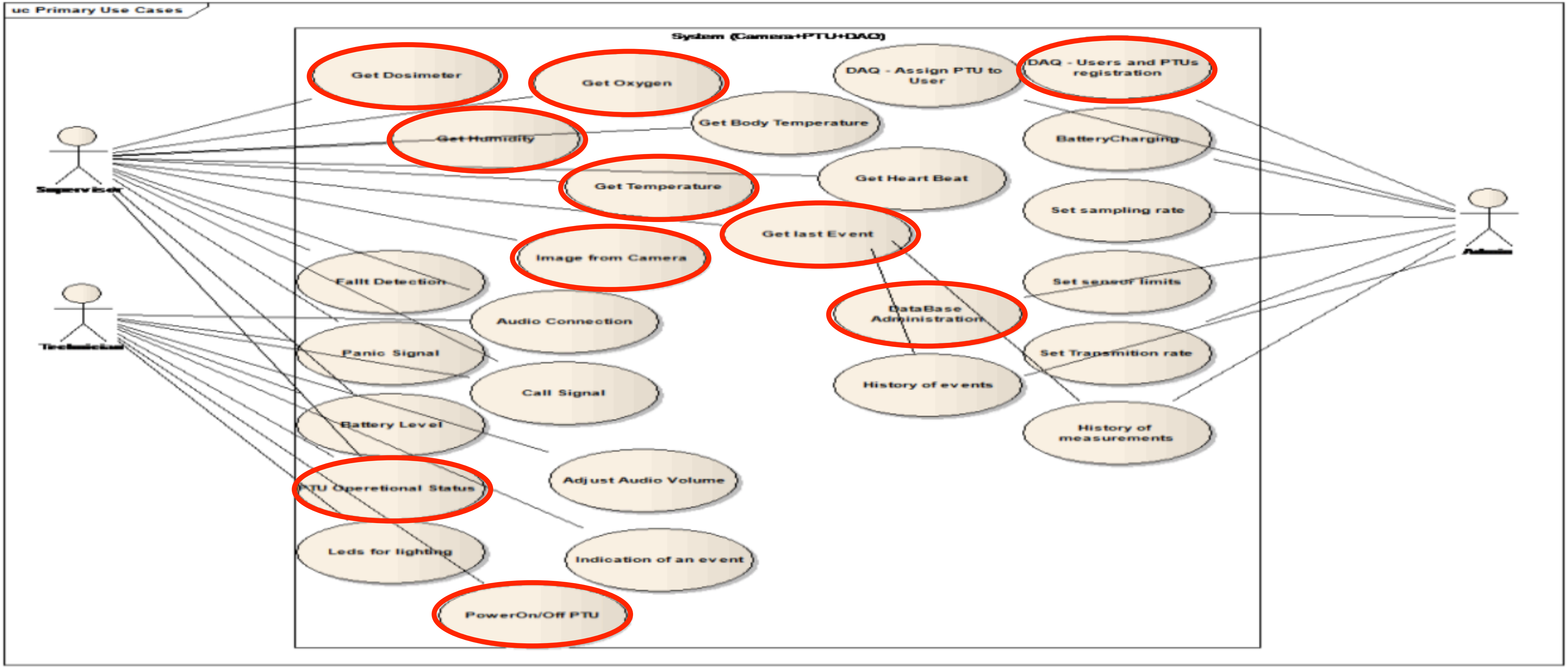
The Camera and the Dosimeter must get **four** indications:

- battery level
- overcoming of a parameter's limit, then a a buzzer is produced
- operational status of the PTU, (sensor connectivity and the network connectivity)
- calling of the supervisor

# The EDUSAFE Project

The collaboration consists: HEP + Economic & Business university teams and Industrial Partners

## 3. The architecture of use case



# The EDUSAFE Project

EDUSAFE

The collaboration consists: HEP + Economic & Business university teams and Industrial Partners

## DAQ/CS operation

The DAQ System can wirelessly acquire various types of data from all the subsystems:

- **1) The Mobile Personal Supervision System (MPSS),** video/audio/radiation data
- **2) The sensor board**, environmental and biological parameters


- <u>Example:</u> Pulse RF module to be connected to the polar heart beat sensor, Oxygen Sensor, Carbon Dioxide sensor, Air Humidity / Temperature sensor, Accelerometers 2 axis for fall detection

# The EDUSAFE Project

The collaboration consists: HEP + Economic & Business university teams and Industrial Partners

EDUSAFE

## DAQ/CS operation

The DAQ System can wirelessly acquire various types of data from all the subsystems:

- **3) The gamma camera,** radiation hot spot localization images
- **4)The dosimeter** used for the radiation measurements
- 5) The mobile **PTU** is responsible for **local data processing** for various sensors, **image, audio data acquisition, visualization** and **wireless interfaced** devices

**Edupix gamma camera** using Timepix chip, a single-pixel read-out chip.

- In case a measurement **exceeds** a certain threshold the CS creates **alarm** notifications
- Once the data are acquired they are shown on the developed **EDUSS GUI** and stored in an Oracle Database for off-line analysis

# The EDUSAFE Project

The collaboration consists: HEP + Economic & Business university teams and Industrial Partners

EDUSAFE

## DAQ/CS System

**1.Mobile Personal Supervision System (MPSS)**

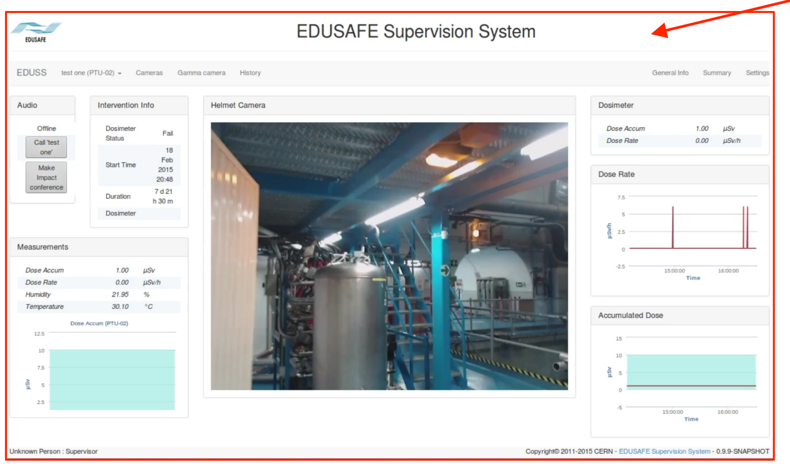
**2. Sensor Board**

**3. Gamma radiation camera**

**4. Operational Dosimeter for radiation data**

**DAQ Server**

**EDUSS GUI**



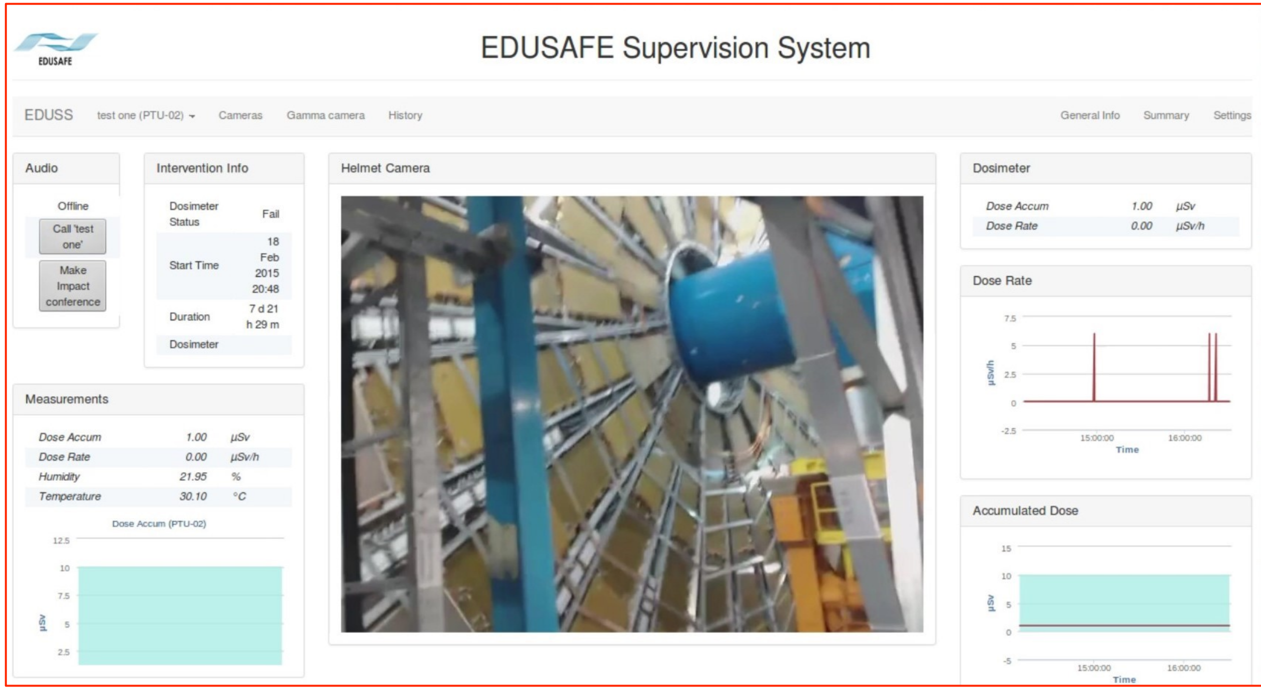

**Oracle DB**

# EDUSS GUI

The EDUSS GUI (**EDUSAFE Supervision System Graphics User Interface**) is developed in order to monitor the various worker sessions and guide the personnel if needed in the **ATLAS cavern**

Through the EDUSS GUI the supervisor can:

- Create multiple **sessions** with the workers in the ATLAS cavern
- **Monitor** every **worker** with **video** streaming and communicate with **audio** connection.
- **Monitor** the **sensor** values and the **gamma radiation** measurements corresponding to the dosimeter of each specific worker.
- Generate and save **plots** of the complete session for each sensor type resulting in faster offline analysis of the acquired data.

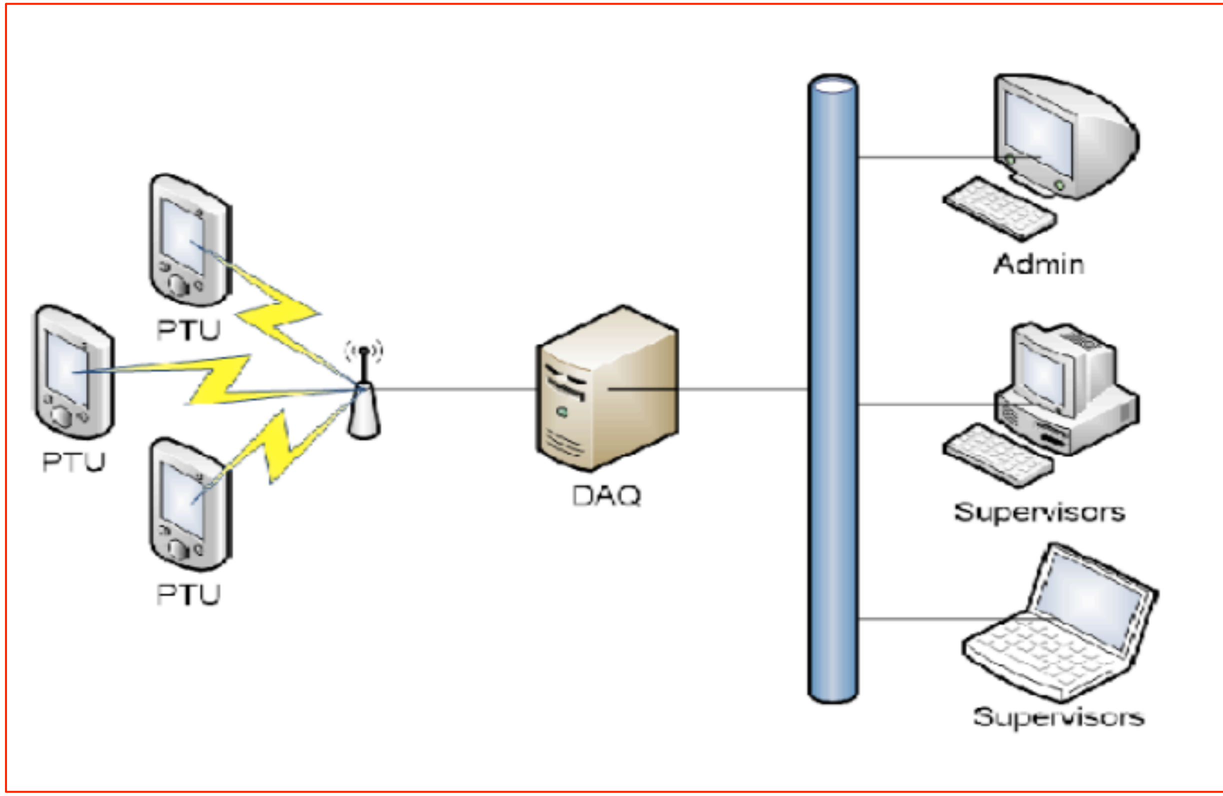


## The architecture of DAQ system

- The Linux based **application** running on main processing module for handling the **measurements** and implement the connection with the DAQ system

- The **portal** running on the main processing module for the basic parameterization of the PTU unit

- The **DAQ Windows Services** establish a **TCP/IP** connection with the video server



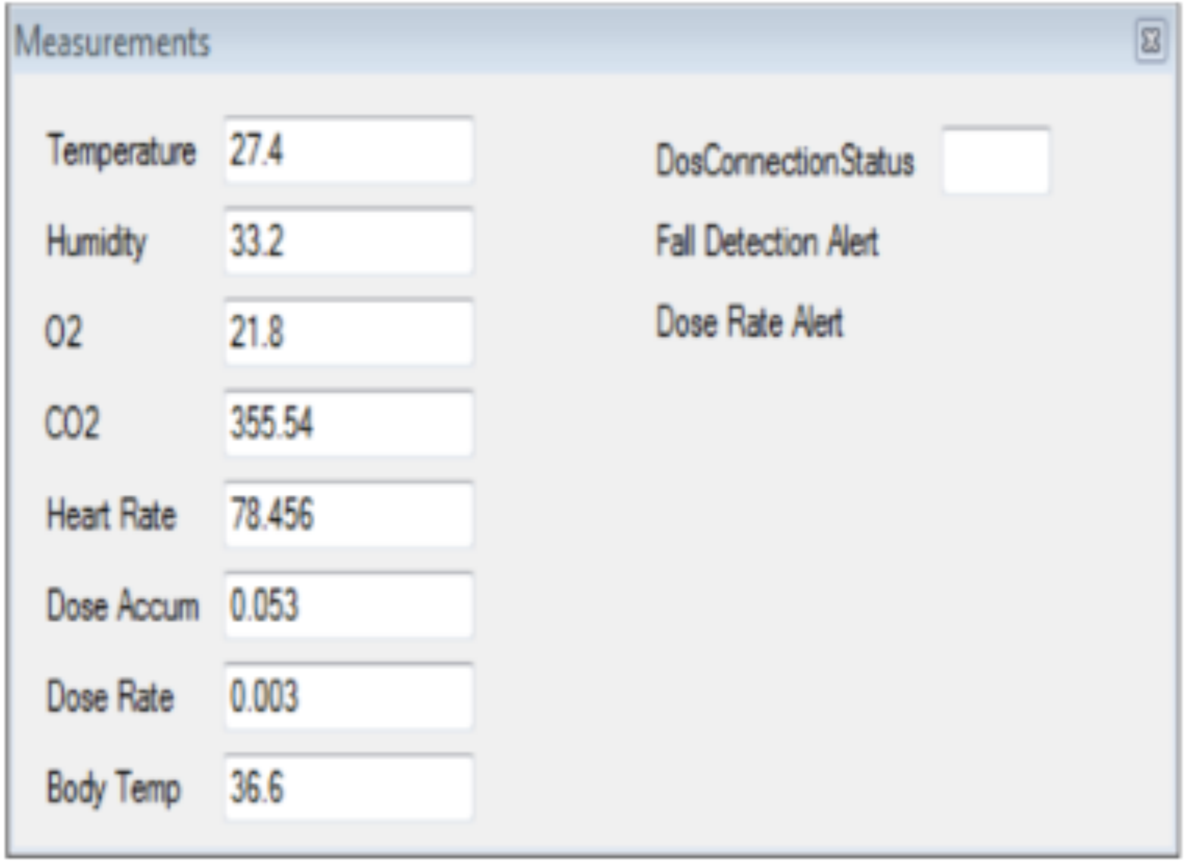
# The EDUSAFE Project

The collaboration consists: HEP + Economic & Business university teams and Industrial Partners

## WPSS prototype evaluation results

- As a **pilot evaluation** of the WPSS prototype, an interview to a **maintenance operator** of the **ATLAS** detector was conducted
- The purpose of the interview was to understand the **requirement**s of our future system
- The **interview** is summarized:

  **a)** The current prototype is good, it needs to be a **modular** form in order to **accommodate more sensors data**
  **b) Local intelligence** are necessary for **environmental** and **health** monitoring information
  **c)** The **image acquisition** of the prototype is functioning well and properly for supervision purposes
  **d)**The scene should be visualized for safety purpose in order to perform **complex activities**
  **e)** The **size** and **power consumption** should be reduced for portable and longtime operations, etc.

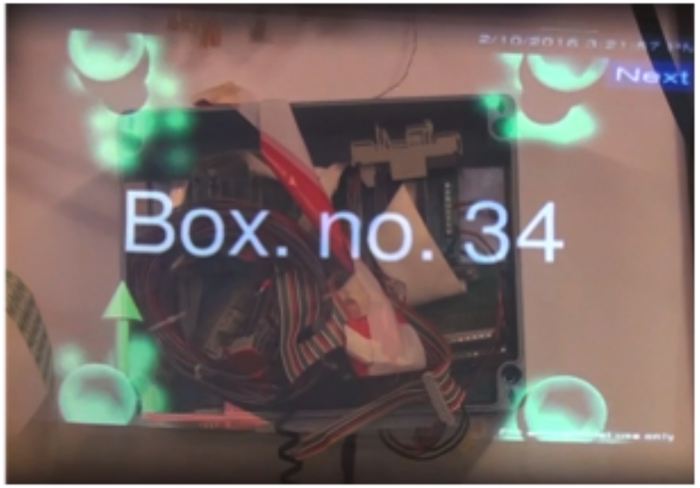


# Modern Augmented Reality based system architecture

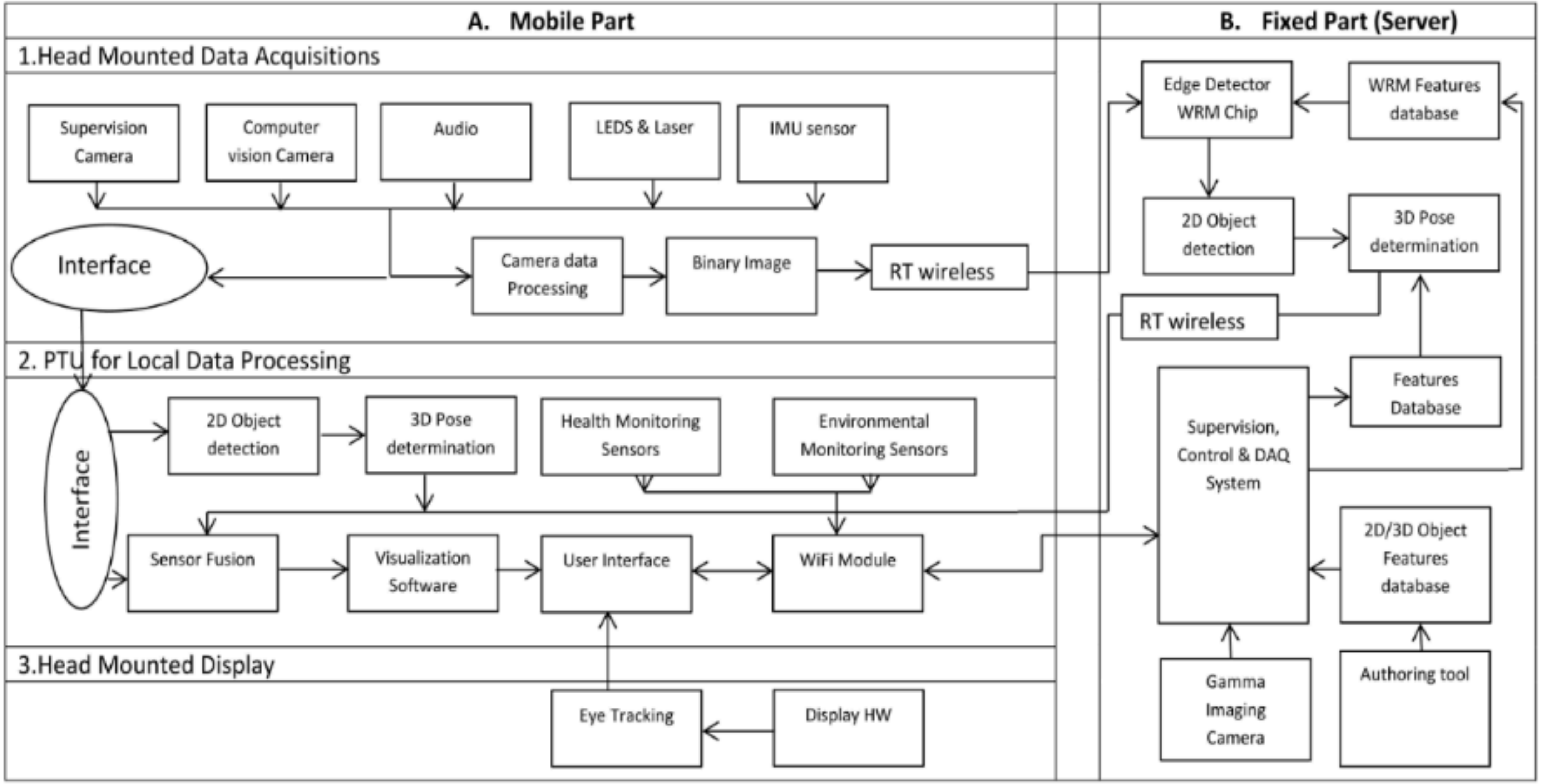
EDUSAFE

- The current **WPSS** system has been:
  - ➢ developed for **limited applications**
  - ➢ analyzed and found that as a **good use case** for some **environmental sensing parameter**, monitoring and **supervision** purposes
  - ➢ confirmed that can easily **protect a worker** in the environment from **hazard element** and fulfill the requirements of AR technology
- **AR/VR technologies** require an **image sensor** to be used with vision algorithms
- The image sensor is the part of a **vision camera** in order to provide the required data **(image data**) to the vision algorithms
- The **cameras**, as part of a **wearable embedded system**, meet a number of requirements related to the processing power, interfaces, size, and weight of the embedded system

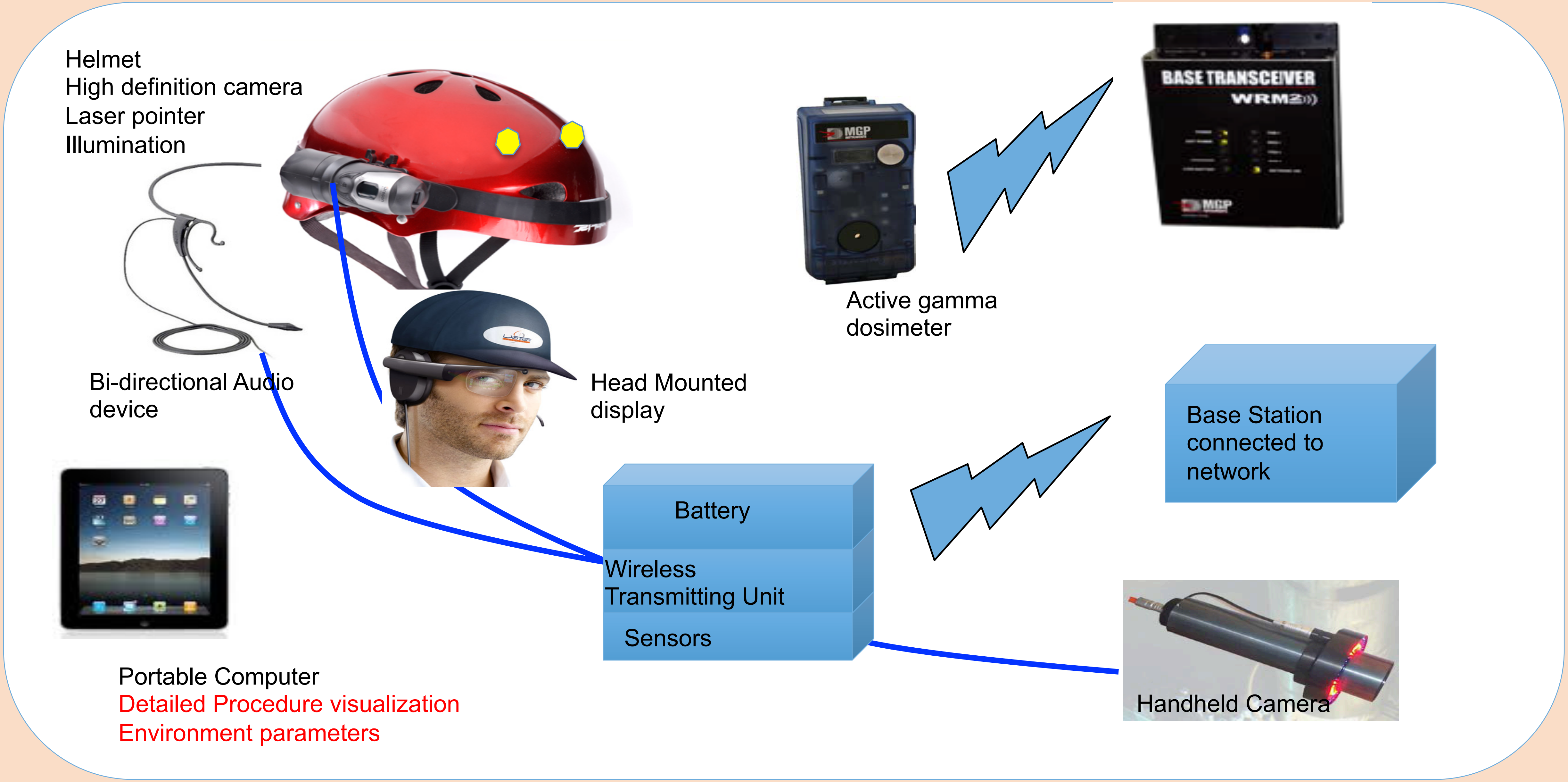
**Augmented reality glasses rendering on a real test demonstration**

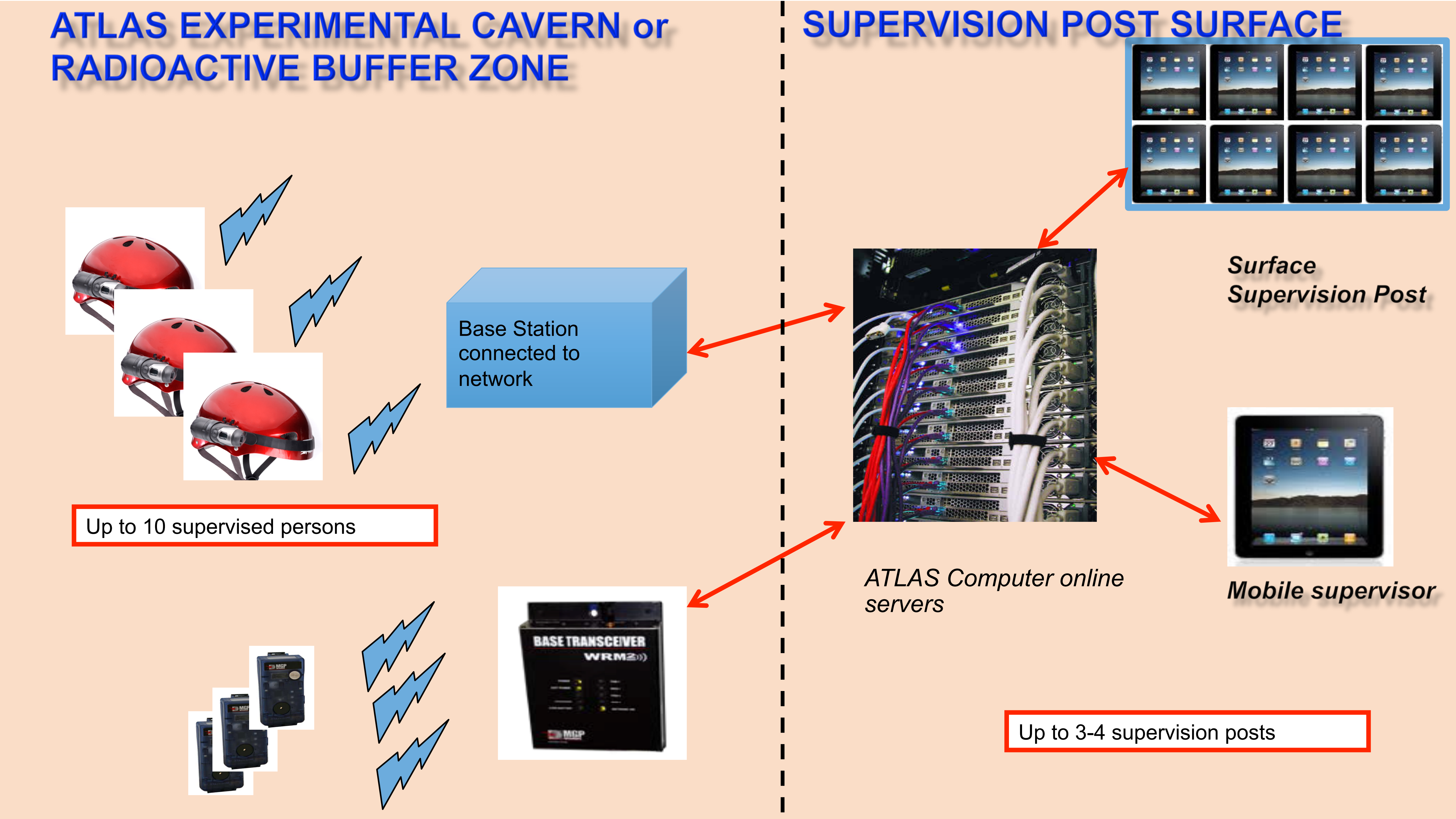


# Advanced system architecture



# Final Result: ATLAS Supervision Post and Augmented Reality Project




ATLAS EXPERIMENTAL CAVERN or
RADIOACTIVE BUFFER ZONE
SUPERVISION POST SURFACE
Base Station connected to network
Up to 10 supervised persons
BASE TRANSCEIVER
WRM2
MGP
Surface Supervision Post
ATLAS Computer online servers
Mobile supervisor
Up to 3-4 supervision posts

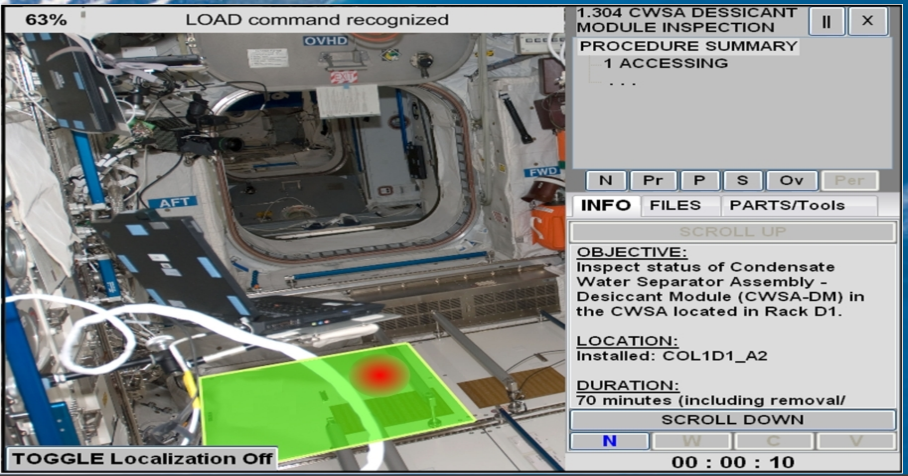
# We are looking for partners ...

**Our possible development partners:**

**ESA, NASA**
**University or institutes (VTT, Columbia …)**
**Hospitals, Companies**
**European Union …**

**Potentially interested industries:**

**Automotive and aerospace industries, Nuclear Power plants military application, etc…**




Astronauts continuing construction of the International Space Station

ATHENS UNIVERSITY OF ECONOMICS AND BUSINESS

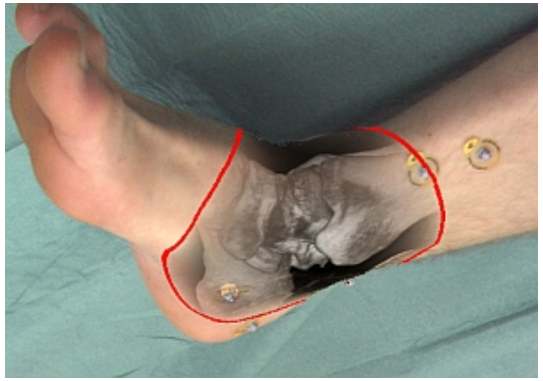
# EDUSAFE System Exploitation next steps

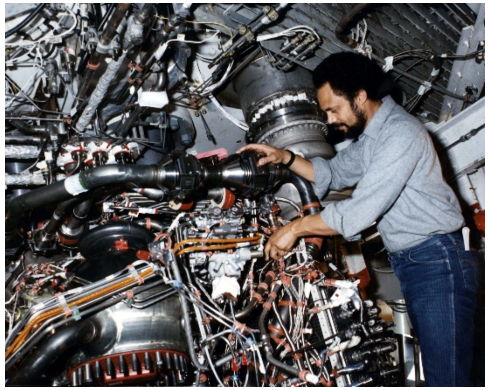
Th. Apostolopoulos, A. Pramatari and V. Mantzios

Athens University of Economics and Business (AUEB)

# Exploitation opportunities

## Medical Applications





## Maintenance process instruction tool



ATHENS UNIVERSITY
OF ECONOMICS
AND BUSINESS

# South by South-west: Interactive

**The 2nd most important event for innovation, high tech and entrepreneurship (March 13-22 2015, Austin, TX)**

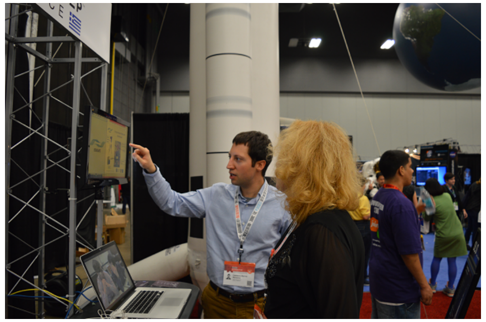
MARCH 13–22, 2015 AUSTIN, TX
SXSW
MUSIC
FILM
INTERACTIVE

- Numerous pitching events
- Entrepreneurship meetups
- High technologies expos from USA labs
- Knowledge Transfer Units from Research Organizations (NASA etc.)
- International high tech startups presentations (Metaio and ODG)
- International Companies representatives
- Capital Investors
- Well-known startups
- Workshops
- Networking events

# EDUSAFE @ SXSW - Exploitation opportunity

**Challenging experience**

- 3 pitches in public
- Numerous contacts and networking
- Great exposure for EDUSAFE work and all partners



**During public pitching event**

A Director from a USA based semiconductors fabrication plant expressed high interest in our system

It was organized a site visit at Fabrication plant for further discussion.

# Semiconductors Fab – Clean-room characteristics


- Very clean and good lighted environment
- Complex maintenance procedure
- No computer aided process has been applied
- No robotic process can be applied
- Big monetary impact of faulty maintenance process
- No monitoring in the maintenance process
- High cost for expert trained maintenance personnel
- Operates 24/7



ATHENS UNIVERSITY
OF ECONOMICS
AND BUSINESS

# Company high level requirements

## Non technical requirements

- Equipment must be **light-weight** and **comfortable** with safety glasses
- Use **server** located in **Company** premises
- Potential **future integration** with Company systems

## Functional requirements

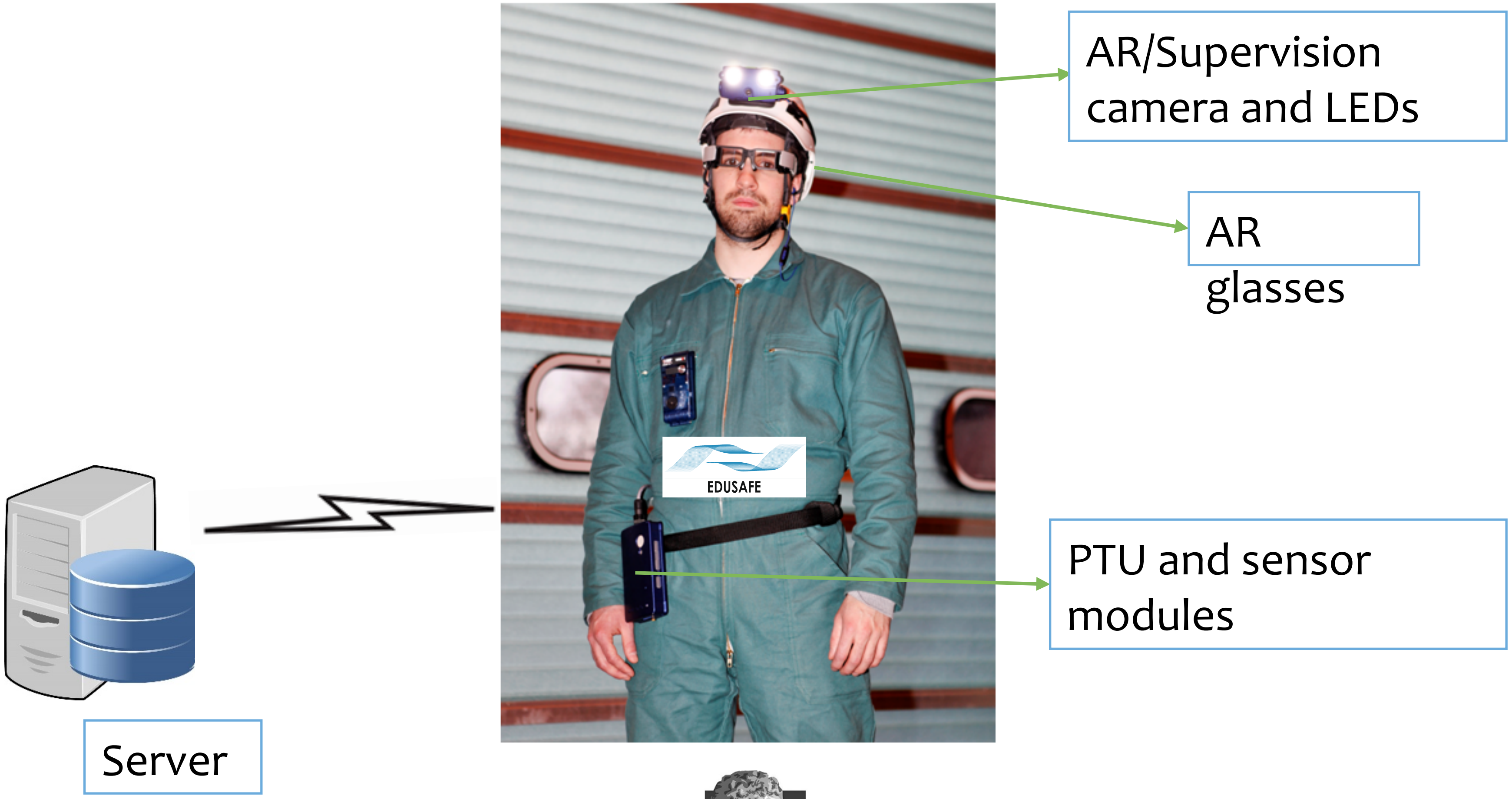
- Read instructions
- Project **augmented content** for maintenance process
- Project specific **technical info** (tolerance values)
- **Verify** (with computer vision) if the work performed is correct (tolerance values)
- **Verify** component positions (using computer vision),
- Record **snapshots**, record video at server
- **voice** commands for user interface
- stream live video to **'supervisor'**
- **hear** 'supervisor' advice/comments **real time**

# EDUSAFE System components for Company

- PTU hardware
- Augmented reality glasses
- Computer vision algorithms
- Server /DAQ
- Authoring tool

No need, for the time being, for gamma imaging camera

# High Level Architecture



# Future collaboration with the Company

- Contact other electronics manufacturers
- Expand in owned Shipyards company
- Physical security control systems

- Communicate with Company Head Quarters for further **funding** and **exploitation** in other applications (e.g. **nuclear industry**)

- As a private company, they need to sign contract with a **private legal entity**
- The formulation of a **spin-out** which will hold the EDUSAFE IP is the best option
- This entity will sign the contract and be the **technology and integration provider** of EDUSAFE
- The Company is not interested in **licensing the technology**, rather participate with equity in a spin-out company

The company is about to invest funds for our technology, so they need to exclude any bureaucratic procedure

# Summary of the technologies used:

- UBI-track
- IMU (Sensor fusion)
- EPFL algorithm
- WRM algorithm
- Sensor board
- Sensors board software
- PTU hardware
- PTU software
- Display hardware
- Display software
- Control unit (touch screen etc.)
- Data Base hardware
- Data Base software
- Server hardware
- Server software
- Gamma imaging camera Hardware
- Gamma imaging camera software

# The EDUSAFE Project

The collaboration consists: HEP + Economic & Business university teams and Industrial Partners

EDUSAFE

## Conclusions

- ✓ A **prototype for WPSS** and an **advanced AR** based modern PSS architecture for personnel safety in harsh environment has been presented
- ✓ The development of the **Augmented Reality** system to be compatible with a wearable use of the system in a highly challenging environment represent an excellent opportunity to integrate today's leading technical knowledge in a product which can become **accessible** to **industry and general public**
- ✓ Software for both mobile and server part maintain a common clock reference and be responsible for tagging all the data accordingly
- ✓ Design pattern encourages that a PSS modular system can be adaptable for various environments with some H/W and S/W constraints
- ✓ Private company (USA) willing to invest to our technology!

**ACKNOWLEDGMENTS**

This research has been supported by a **Marie Curie Initial Training Network** project of the European Community's FP7 Program under contract number PITN-G2012-316919-EDUSAFE