The integrated supervision and control system of the Gran Sasso mountain

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Abstract

A high safety and security level of a complex system is very difficult to be reached, guaranteed and managed if the system is characterized by a peculiar complexity and physical extension, due to the elevate number of parameters to be checked and controlled.
The use of human resources needs an elevate number of personnel members that could not only be unable to reach the desired goal but could also be exposed to severe risks in the presence of dangerous and emergency situations.
For this reason it is necessary to use integrated supervision and control systems that are capable of manage the elevate number of parameters involved, reducing the number of personnel members and increasing their functionalities and operativity.
In this paper the integrated supervision and control system of the Gran Sasso mountain (Italy), characterized by a high and unique complexity from the international point of view, is illustrated.
Keywords: integrated system, telecommunication system, safety system, security system, emergency management system.

1 Introduction

The Gran Sasso ("big rock") mountain is located in the centre of Italy, about 120 km est of Rome, between the L'Aquila city province and Teramo city province, in the Abruzzo region.
It belongs to a system of mountains that practically separates the Adriatic sea (east) from Tirrenian sea (west) in the middle of Italy.
The higher peak of Gran Sasso mountain is represented by Corno Grande ("big horn"), that is about 3000 metres above the sea level.

Due to the elevate altitude, even if the mountain is not so far from the Adriatic sea, a permanent glacier is also present.
On the high plane of Gran Sasso mountain, named Campo Imperatore ("Emperor high plane") is also present a sky resort.
Under the Gran Sasso mountain there is a separate double highway tunnel (one tunnel for traffic in the L'Aquila – Teramo direction and one tunnel in the Teramo – L'Aquila direction). These tunnels take the traffic from the west to the east side of central Italy and vice versa and they represent a vital connection for road traffic. The length of tunnel is of about 10 kms, that represent the second road tunnel of Italy, in term of length, after the Monte Bianco ("white mountain"), that is anyway one of the longer road tunnel at the international level (even if single tunnel while the Gran Sasso is double tunnel).

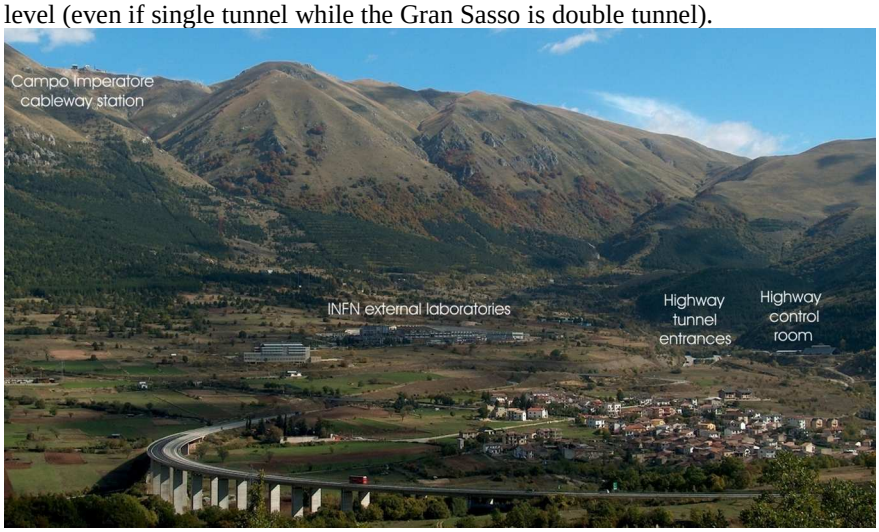

Fig.1 Partial view of Gran Sasso mountain from L'Aquila side.

Inside the mountain the underground Gran Sasso mountain National Laboratories (GSNL) of Italian Institute of Nuclear Physics (INFN) are also present. They are located 1400 meters under the central rocky mass, named Eagle Mountain.
The offices and the directional centre are located 1 km away from the Assergi highway exit (in the L'Aquila city province) and they extend on a 12.000 square meters surface while some technical installations (fanning, electrical supply, etc.) are located on the other side of Gran Sasso mountain (in the Teramo city province) just outside the highway tunnel, in a site named Casale S. Nicola location.
The entrance of GSNL is located in the Teramo – L'Aquila direction tunnel using a passage reserved to the laboratory traffic and created by means of a narrowing of about 1 km of the tunnel road in the correspondence of underground laboratories.
The GSNL are the biggest and most important underground laboratories of the world characterized by a unique environment for the kind of research that is made inside them. Further, they have been realized on purpose and not

recovering or adapting already existing structures, such as active or closed mine (KAMIOKANDE in Japan and SNO in Canada).

Fig.2 3D view of the laboratories and part of highway tunnels.

The design, the approval and the public financing have been possible thanks to the simultaneous drilling and construction, in '70-'80 years, of the highway tunnels in the same zone. The GSNL realization started in 1982 and the construction of the first experimental apparatus started only 4 years later, in 1986, when the first tunnel was opened to the public traffic. The underground laboratories are mainly constituted by 3 experimental rooms, whose dimensions are about 100 x 20 x 20 meters, and by a series of connection tunnels that are used for the installations necessary for the correct functioning of the laboratories and for hosting secondary and reduced dimension experimental devices. The total internal volume is about 180.000 m^3.

Actually there are about 15 experiments currently working in the 3 experimental rooms and in some connection tunnels.

It is there evident that in the Gran Sasso mountain are present a lot of subjects that make specific activities (INFN laboratories, highway, aqueduct, etc.) and for this reason the Gran Sasso mountain represents a wide and complex system where each component interacts, unavoidably, with the other components. In fact, for example, the highway represents the only entrance to the laboratories, where not only people but also all the installations (such as electrical, fanning, cooling, telecommunications, etc.) that guarantee the correct functioning and the safety of laboratories, must pass through. This implies that a possible accident inside the highway tunnels can compromise not only the stability and reliability of the installations of laboratories but also the capability for fire brigades, highway tunnel personnel and emergency teams of reaching the laboratories. The

same happens if an accident takes place inside the laboratories. For this reason the emergency plans related to one of the subjects which operates inside the Gran Sasso mountain must consider also the other present subjects.
This characteristic gives to Gran Sasso mountain an extreme oneness at the international level.

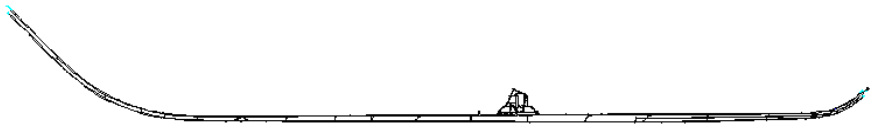

Fig. 3 Plant of highway tunnels with INFN laboratories (in the middle, upper side). L'Aquila city direction is on the left side while Teramo direction is on the right side. Tunnels are about 10 kms long.

Due to the multitude of people, systems, devices and installations that must be controlled and that must communicate each other, it is evident that the Gran Sasso mountain, to be managed securely in the best way, needs to use intensively advanced technologies finalized to obtain a high and efficient quality of functionality, performances and services [1-5].
To increase the safety and security level of people that operate in Gran Sasso and to protect the unique natural environment, in July 2003 the Italian Government, through the Department of Civil Protection, designated a Delegate Commissioner of Government.
The integrated supervision and control system presented in this paper was studied and designed by the author during his activity of consultant of Delegate Commissioner of Government, concerning the safety and security aspects of Gran Sasso.

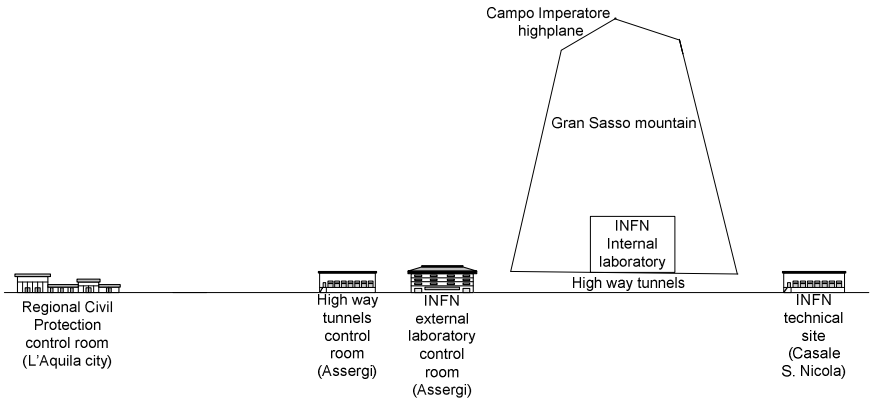

Fig. 4 Transversal schematization of Gran Sasso mountain system.

Due to the complexity of Gran Sasso mountain and of the subjects that operate in it, the mentioned system represents a unique object at the international level in term of functionalities and reliability, greatly increasing the safety and security of people and of the surrounding environment.

The scope of the paper is to illustrate the mentioned advanced system, the difficulties found for its design and the results obtained.

2 The integrated supervision and control system

The designed system is aimed at improving safety, security and emergency management in a totally automatic and immediate way or at aiding the personnel by means of an expertise information system, allowing the control and activation of any component present in Gran Sasso and connected to the supervision system, by means of local or remote consoles.
The system not only is aimed at integrally control safety, security and emergency but it is also aimed at providing a series of advanced services (such as a innovative radio communication system) to the whole community that operates inside it or on it or live in the surroundings.
The considered integrated system allows the maximum integration and communication of all the installations, devices and systems present in the Gran Sasso, both inside or outside it, and it guarantees their control and management in a totally automatic way, according to predefined procedures.
The system includes an advanced radio communication and localization system, capable of operating both inside and outside Gran Sasso mountain, covering a wide area that extends from L'Aquila city to Teramo city and passing above it through Campo Imperatore high plane. This radio communication system, extremely innovative, is capable of ensuring an instantaneous link between all the subjects involved in safety, security and emergency situations and can be used, in ordinary conditions, from all the enabled subjects that operates inside, outside or in the nearby of Gran Sasso mountain.
The system integrates the following components present in Gran Sasso mountain:

1) GSNL laboratories:
   a) radio communication and localization of safety, security and emergency personnel;
   b) wireless communication, localization and advanced information service of personnel [6];
   c) video surveillance TV (internal and external);
   d) access control;
   e) anti-intrusion;
   f) public address;
   g) video information service;
   h) internal parking management system:
   i) interface with incidental lost liquid monitoring system, water source quality monitoring, fanning system, cooling system, experimental devices operating in the laboratories, electrical supply installations, fire and dangerous gas monitoring systems, environmental monitoring systems;
2) highway tunnels:
   a) radio communication and localization of safety, security and emergency personnel;
   b) predisposition for cellular phone communication system installation;

c) video surveillance TV;
d) optical fibre fire sensor;
e) interface with technical installations, traffic management system, environmental monitoring systems;

3) external:
a) radio communication and localization of safety, security and emergency personnel;
b) interface with various systems and installations, environmental monitoring systems.

The system guarantees a high degree of integration between the GSNL subsystem, the highway tunnels subsystem and the external subsystem, ensuring a correct and immediate control of all data and significant events for safety, security and emergency of Gran Sasso mountain.
In this way it has been designed a system whose functionalities are really superior with respect to the functionalities of single subsystems, devices, installations or elements.
The system operates thanks to an advanced telecommunication subsystem, characterized by a high reliability, that is capable of working in the presence of the severe climate conditions present inside and outside the mountain. The telecommunication subsystem is described later.
The designed system is characterized by a high degree of modularity and expandability so that it is possible, in future, to add and integrate any other installation, device or apparatus in any point, inside or outside the Gran Sasso mountain, guaranteeing always the full control of any components present in GSNL, highway tunnels or anywhere.
The integrated system concentrates the alarm signalling generated by the various installations and devices in 4 control rooms, unifying the management procedures and optimizing the needs of personnel resources necessary for organization and mainteinance.
The 4 control rooms are:

1) internal GSNL;
2) external GSNL;
3) external high way tunnels;
4) regional Civil Protection (L'Aquila city).

The system is extremely modular and flexible and allows to add, at any time, other control rooms or management consoles, according to specific needs that could appear in future.
The control room of regional Civil Protection is designed to transmit, in normal or emergency situations, significative data or alarm signalling to other subjects such as:

1) National Civil Protection;
2) fire brigades;
3) police;
4) aqueducts management societies;
5) national park guard;
6) regional water authority;
7) Abruzzo regional administration;
8) L'Aquila provincial administration;

9) Teramo provincial administration;
10) L'Aquila prefecture
11) Teramo prefecture;
12) local town administrations;

and any other subjects that could be individuated in a second time and located even at great distance from Gran Sasso mountain.

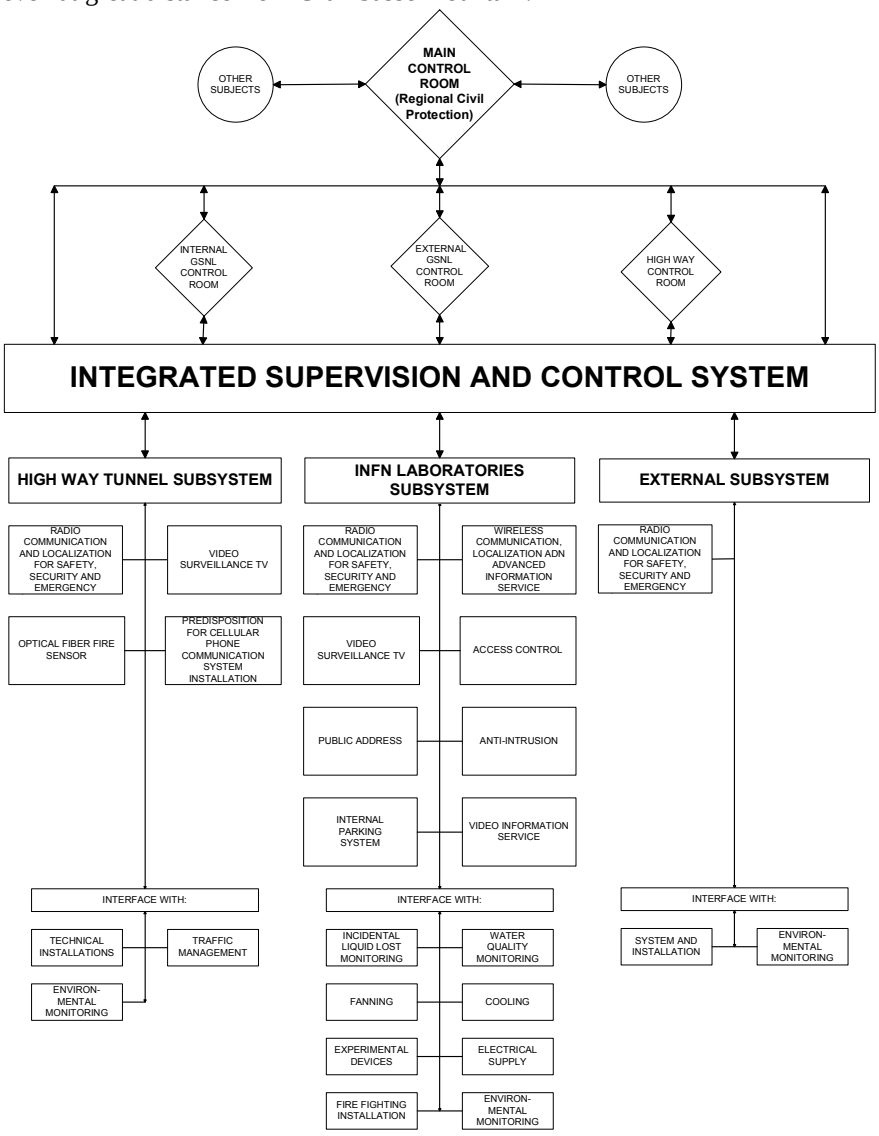

Fig. 4 Functional block diagram of the integrated supervision and control system.

The correct integration of installations and apparati is reached coordinating the design of installations with the operative needs of laboratories and highway tunnels, from one side, and improving the use of each technological components to better use their functional features, from the other side.
The video surveillance is therefore used, for example, to view the zone where there is an alarm signalling, restricting the physical movement of safety and security personnel only to the real needs, increasing their efficiency and at the same time their safety, keeping they far away from dangerous situations.
The supervision system works according to proper manuals of procedures agreed with Civil Protection, interested Prefectures, Laboratories, highway society and all the other interested subjects.
The consoles located in the different control rooms can manage, according to the needs and the assigned operative level, every component of the system, acting only as display units or as operative activation units. These consoles can be located even at a great distance from Gran Sasso, thanks to the transmitting capabilities owned by the telecommunication subsystem.
The system also allows the enabled radio units (radio communications or wireless) to operate as mobile consoles.

2.1 Design criteria of the system

The system was designed according to high reliability standards, since it must works in any severe conditions.
The system is divided into autonomous subsystems for 2 mains reason:

1) in case of malfunctioning of any subsystem, the other subsystems can continue to operate, ensuring their functionalities;
2) due to its dimension and physical extension, its integral realization takes a certain time. In this way it is possible to realize each single subsystem that can immediately operates independently from the other subsystems.

Any subsystem is characterized by a high reliability, being supplied from different electrical sources, properly backed-up, that allow them to operate even in the absence of the main electrical supply for a long time.
Any component of the system is constantly and automatically checked and monitored from the functionality point of view, so that any malfunctioning is immediately individuated: in this case the necessary alarm signalling is sent to the maintenance personnel to activate the repairing procedures.
The system can anyway operate even with reduced performances, with one or more than one damaged components, due to the severe operative conditions such as the one imposed by the climate conditions and from possible severe accident (i.e. for example a car accident, with consequent fire, in the highway tunnels).
The main subsystems are:

1) the INFN laboratories subsystem;
2) the highway tunnel subsystem;
3) the external subsystem.

According to this division, even the functional subsystems (i.e. main telecommunication subsystem; radio communication and localization of safety, security and emergency personnel - TETRA system; etc.) are divided to serve, separately and independently, the 3 subsystems, conserving anyway their unity.

The system was designed to reduce, as more as possible, the environmental impact, providing its advanced functionalities without any interference with the Gran Sasso environment from any point of view.

2.2 Design of telecommunication subsystem

The design of the telecommunication subsystem started with the analysis of data flows that must be carried by the system with a high velocity, reliability and security [5].
The telecommunication subsystem is capable of operating, with high performances, in the severe climate conditions present inside or outside Gran Sasso mountain, ensuring a high security level of data that flow inside it.
The telecommunication system is composed by 4 subsystems:

1) main telecommunication subsystem;
2) radio communication and localization of safety, security and emergency personnel;
3) wireless communication, localization and advanced information service of personnel;
4) predisposition for cellular phone communication system installation in the highway tunnels.

The main telecommunication subsystem is composed by a fixed infrastructure that is totally redundant to increase the reliability of the whole system. It is capable of auto-reconfiguration in case of damage of part of it due to incidental events. It represents the telecommunication backbone of the whole system, allowing the communication between any element connected to the system and with the control rooms.
The fixed infrastructure, since it extends even in the highway tunnels, is characterized by a loop architecture whose branches extend in the different tunnels. In this way, in the presence of a heavy road accident inside one tunnel that could damage a part of the tunnel itself and the related installations, the telecommunications are ensured through the other branch of the loop that extends inside the other tunnel.
To increase the reliability of the fixed infrastructure, two different fixed infrastructures are used: one for INFN laboratories subsystem and one for highway tunnel subsystem. The two infrastructure use a loop architecture that is installed in different zones of the tunnels: in this way, an incidental event that should damage a part of one loop cannot damage the other loop.
To guarantee the maximum level of reliability, the main telecommunication subsystem uses microwave repeaters: in this way are always guaranteed two redundant channel (ground channel and air channel) to ensure the communications to reach the final destination. A microwave repeater in installed on the already existing pylon on Campo Imperatore, to connect the control rooms of INFN laboratories (external), highway tunnel and Civil Protection in L'Aquila city (about 15 km away), all located on the L'Aquila province side of Gran Sasso. Another microwave repeater is installed on an already existing pylon located in the technical zone of Casale S. Nicola of INFN laboratories to connect the Teramo province side of Gran Sasso with the other side and with the top of

Prati di Tivo, where a radio base station is present (that is illustrated later), ensuring radio coverage until Teramo city.
The radio communication and localization of safety, security and emergency personnel is designed to allow a prompt diffusion of information and a rapid response of personnel involved in any emergency situation. It is strongly integrated with the other components of the telecommunication system.
Due to the variety of performance requested, a collective access radio system has been designed. It is capable of satisfying all the communication needs of the Gran Sasso subjects. The mobile system is composed by a series of base stations (such as ordinary GSM or UMTS mobile communication system) connected to a central unit that manages and controls the service of radio units of the users.
In a collective access radio system the frequency are dynamically assigned to the users, according to the their needs, allowing an efficient and dynamic management of the system.
The radio communication system allows the interconnection with the internal and the external telephone net, guaranteeing a high level of connectivity.
The used digital technology shows the following advantages:
1) better quality of vocal messages;
2) higher transmission and receiving velocity;
3) lower dependence from signal receiving level;
4) higher security of conversation thanks to the used cryptographic algorithm;
5) capabilities of using the mobile units not only as phones but also as data terminals to transmit and receive any kind of information.
Every used radio link can be divided in 4 different channels, that are used singularly or together as a function of the necessary transmission band.
The mobile system checks continuously the coding/decoding quality of the voice, allowing an optimal communication service even in the presence of noise.
The system allows a multi-level user authentication (user - mobile system; mobile system – fixed net; network – network; user - user), using high security cryptographic algorithms. It also supports a multi-traffic profile which allows voice and data service with the same terminal at the same time. The voice traffic is based on a TDMA (Time Division Multiplexing Access) transmission technology while the data traffic is based on a PDO (Packet Data Optimized) transmission technology. The used PDO technology also allows a full compatibility with TCP/IP protocol and all the related facilities.
Further, the mobile system is characterized by a high security level through:
1) use of mutual authentication (radio unit – base station and vice versa);
2) cryptographic communications using both static and dynamic keys;
3) support of end to end cryptographic communications;
4) disabling capabilities of stolen or lost radio units;
5) management of data directly through IP network using ciphered protocol.
The radiocommunicaton system offers the following vocal services:
1) individual call: this service is equivalent to the communication through a cellular phone (i.e. a user calls another user);
2) group call: a user calls a defined group. Every member of the group can listen and talk everybody. The group is defined in a flexible way, that is each user can be added to the group or deleted from the group at any time;

3) direct call: two or mores radio units communicate directly without the support of the base station;
4) broadcast call: that is a unidirectional point-multipoint call in a certain zone. The zone and the users can be dynamically defined;
5) emergency call: that allows to make a high priority call pressing an emergency button on the radio unit;
6) include call: that allows of calling or inserting in a call one or more supplementary users;
7) open channel: a group of users can talk on a certain radio channel and all the users can listen and talk at any time.

The radio communication system offers also data services. It is composed by a control centre, called master site (MS) and from a variable number of base stations (BS) positioned on the territory. The emitted power is reduced, as more as possible, to guarantee a high quality of service and a reduced emission of electromagnetic fields. The BSs are located on Campo Imperatore and INFN external laboratory, to ensure the service on the L'Aquila Gran Sasso side; in INFN Casale S. Nicola technical site and Prati di Tivo to ensure the service on Teramo province Gran Sasso side. Some micro BSs are present inside highway tunnels and underground laboratories to distribute the low level electromagnetic field by means of a proper radiating cable to ensure a full coverage of the Gran Sasso interior.

The designed radio communication system allows, using a common infrastructure, a lot of users to communicate without reciprocal interference and with a high reliability, being promptly localized for safety, security and emergency purpose.

Another communication subsystem is represented by the wireless network. This system uses light portable terminals carried by any person that goes to the underground laboratories. This system uses a wireless LAN, distributed all over the internal and external laboratories, which allows localization of all the people and any kind of communication (voice, external and internal phone, video, data, etc.). The wireless system allows the implementation of advanced services, including the capability of controlling, if the user is enabled, specific components of the supervision system or receive alarm signalling by it.

To increase the safety level of people inside the laboratory, in case of malfunctioning of a wireless terminal, it is also planned the use of reduced weight wireless identification device (WID) that send a signal to the wireless LAN periodically. The wireless system is therefore able to localized the owner of WID in a totally autonomous way with respect to the wireless terminal. In this way it is always possible to localize, with high precision, all people inside laboratories that is an important feature in case of emergency evacuation.

The last telecommunication subsystem is represented by the cellular phone in the highway tunnels (only predisposition for installation is designed, since the operative frequencies are already assigned to private cellular companies that can now install easily their systems inside tunnel). It allows significant services such as public communication of car drives, very important in normal and emergency conditions.

The system is complementary to the wireless service, since the wireless terminals are also endowed with cellular phone capabilities. In this way the personnel

directed to the laboratories can fully utilise wireless service using the cellular net.
The cellular net uses the same radiating wire used by the other radio communication systems to reduce, as more as possible, the installation of wires in the highway tunnels. It is also characterized by a reduced emission of electromagnetic fields, since the power is gradually released along the cable and not emitted by means of antennas.
The telecommunication system has been designed to be capable of using satellite connections so that it is possible to ensure its services, even with a reduced velocity due to satellite link limitations, all over the world.

3 Conclusions

The safety, security and emergency management in complex contests such as the one of Gran Sasso mountain needs a detailed analysis of risks and dangers that must be faced and a correct study, design and realization of an efficient supervision and control system which is capable of integrating the different subsystems, devices, and installations present, ensuring the maximum reciprocal integration of the different operative subjects.
In this way it has been possible to design a powerful and versatile integrated system that guarantees a high level of safety and security to the Gran Sasso community.

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