A GPS/EGNOS Local Element Integrated with the VHF Communication Infrastructure Under Development in the POP-ART Project

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Abstract. The paper aims at introducing the on-going activities around the design and development of a network-based positioning system exploiting the advantages of both the European Geostationary Navigation Overlay System (EGNOS) and the VHF communication infrastructure with the goal to support the Alpine Rescue Teams in the management of search and rescue operations.

Such an innovative integration strategy among analog communication channels and EGNOS is the key topic of a project named Precise Operation Positioning for Alpine Rescue Teams (POP-ART) co-funded by the Galileo Joint Undertaking as specific action toward the support of innovative ideas around EGNOS and Galileo proposed by Small Medium Enterprises (SME).

The positioning system is based on the raw GPS measurements collected by the users and transmitted to a Local Element by VHF radio channels (or GPRS when available).

The POP-ART activities are based on pre-existing works already presented in [1] [3].

The goal of the paper is to provide the latest information on the results already achieved within the project as well as the perspective on the expected performance thanks to several analyses on the EGNOS features.

In particular, the results demonstrate that the system fully exploits the improvement given by the EGNOS signals, ensuring a suitable level of accuracy in the positioning for a larger time with respect to standalone GPS positioning.

1 Introduction

This paper is focused on the overall description of the system architecture for an innovative integrated GPS/EGNOS/VHF Local Element as proposed in the Precise Operation Positioning for Alpine Rescue Teams (POP-ART) project [2].

The POP-ART project is part of the projects started under the 2nd call area 3 of the 6th Framework Programme for Galileo Research and Development This project is partially funded by the Galileo Joint Undertaking and coordinated by Sist&Matica that is an Italian SME. Moreover the POP-ART consortium is composed by the Institut für Erdmessung und Navigation (IfEN) that is a SME from Germany and the Istituto Superiore Mario Boella (ISMB) that is an Italian research institute.

With the goal of supporting the operations of the Alpine Rescue Teams, POP-ART aims to ease the real-time management and coordination of the on-field resources: precise positions of all the team members are calculated at the control centre level thanks to the use of the EGNOS augmentation data. Here the so called Network-Assisted Local Element will be realized. As a consequence, this architecture allows the operations coordinator to provide very precise directions to all the rescuers, allowing a sensible reduction of the intervention time, essential for the success of search and rescue operations.

The paper is organized as in the following: Section 2 provides some preliminary statistics about the Corpo Nazionale Soccorso Alpino e Speleologico (CNSAS) operations and presents the collaboration between the POP-ART consortium and the CNSAS. Such data justify the request from CNSAS to have a technological platform supporting their operations.

Section 3 provides a description of the system architecture, whilst Section 4 describes the expected performance of the final prototype on the basis of the EGNOS performance for static and dynamic conditions. Section 5 presents the overall project planning, while Section 6 proposes some possible R&D activities that will follow the POP-ART.

It has to be remarked that POP-ART kicked-off in March 2006. Therefore, some of the technical results here presented has to be considered as pre-existing know-how of the authors and then useful in the project development.

2 CNSAS Involvement in the POP-ART Requirement Definition

The POP-ART has to end with a ready to use system prototype; therefore, since the beginning of the project the consortium directly involved the CNSAS that is the Italian Alpine Rescue Team [5]. All the system requirements at both functional and services levels has been obtained through specific interview with CNSAS representatives, achieving a high level of system acceptance from the persons that will operate the prototype.

Hereafter some statistics related to the CNSAS interventions in Italy are reported. These graphs are useful in order to understand the strength and the potential advantages of a centralized monitoring system like POP-ART for search and rescuer operations.

It has to be remarked that the information sketched below are heavily used in the POP-ART requirement analysis for the definition of the system architecture.

The raising numbers of people who goes to the mountains has dramatically increased the number of interventions of the Rescue teams to help people injured or in danger situations, as highlighted by the Fig. 1 that shows the statistics about

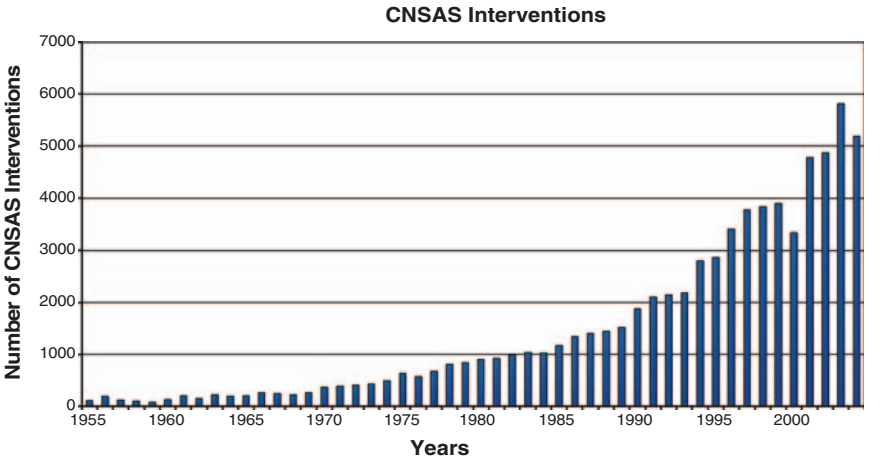

Fig. 1. CNSAS number of interventions per years from 1955 to 2004.

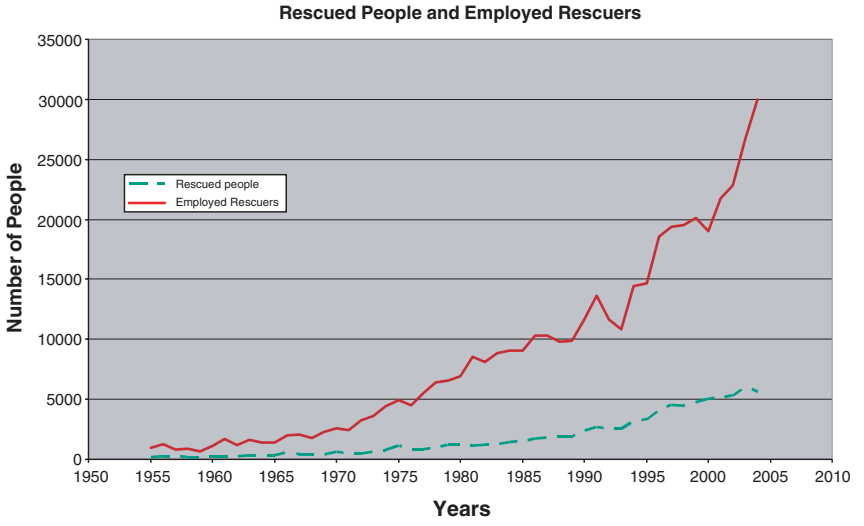

Fig. 2. Comparison between rescued people (dashed line) and number of employed rescuers (full line) per year from 1955 to 2004.

interventions from 1955 to 2004. Consequently, the number of rescuers employed in the operations has considerably increased, as shown in Fig. 2.

The trend shows in these graphs with an increasing in the CNSAS interventions number and in the employed rescuers confirms that the use of an automatic and precise monitoring system like POP-ART will became soon necessary in order to make easy the operation management and to improve the safety of both the rescued people and the rescuers.

Figure 3 shows the average number of teams' components per year; it is possible to observe that this number has always remained under 10 people. Furthermore this number has stayed around 5 people in the lasts years. This indication has to be taken into account into the POP-ART architectural design especially for the definition of

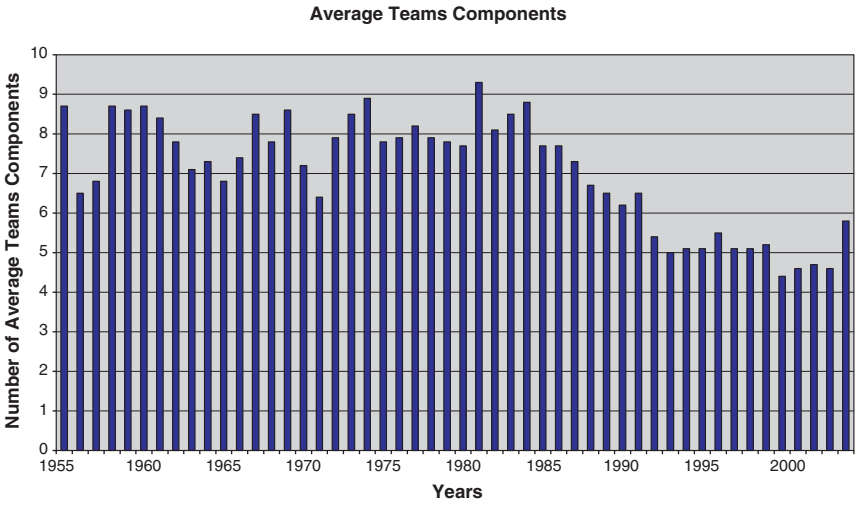

Fig. 3. Average components number of an alpine rescue team employed in search and rescue operations.

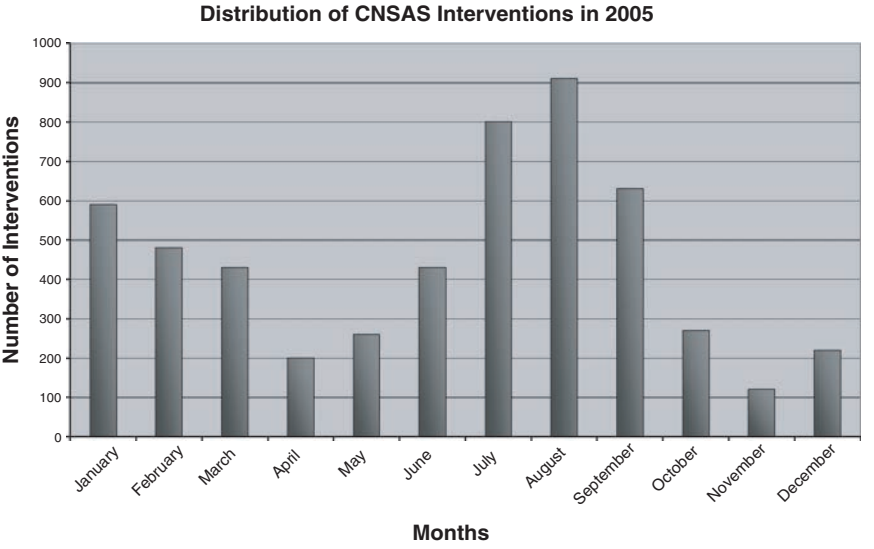

Fig. 4. Distribution of CNSAS intervention over the 2005. The graph highlights the large interventions number during the summer; it is due to the increasing of the tourist excursions.

the communication strategy that represents a key point for the success of the POP-ART system.

Figure 4 represents an example of statistic information about the CNSAS activities in the 2005, which are the most recent at the time of writing. It shows the distribution over the 2005 of the CNSAS interventions per month. The graphs highlights that most of the interventions are concentrated during the summer, especially in August, due to the strong presence of tourists in the mountains areas for holidays or for excursions.

This large number of interventions in a limited time window demonstrates the requirement to improve the management of CNSAS interventions; hence it justifies the introduction of POP-ART system for the alpine rescue teams in order to conduct the operations with higher level of efficiency.

3 POP-ART System Architecture

According to the input received by the CNSAS representatives of the Piemonte region, nowadays during standard rescue operations each rescuer is equipped with a VHF radio transceiver transmitting on a reserved and certified frequency band and in some cases with a GPS receiver. The position, when available, is communicated by voice on the radio channel to the control centre where the operations coordinator manually records on a map the received positions in order to have a complete view of all the rescuers. Such positioning information are then displayed in order to allow the operations coordination on a personal computer at the control center side using a 2D cartographic interface. All these constituent blocks are shown in Fig. 5.

The goal of POP-ART is to upgrade such system in order to provide to rescuers an automatic real-time localization infrastructure with high accuracy and availability.

In particular, the main drivers that have been taken into account are listed in the following:

- The positioning system must reach a high degree of availability and reliability, especially in mountainous environments;
- POP-ART must rely on VHF radios already in use by the Alpine Rescue Teams. GPRS data communications has to be considered as a nice to have feature due to its unreliability in critical situation; hence it cannot be use as the main COM infrastructure. It has to be remarked that CNSAS of the Piemonte region invested many financial resources in order to have a full coverage of VHF in the Alpine area. Therefore, such operative infrastructure guarantees today the best

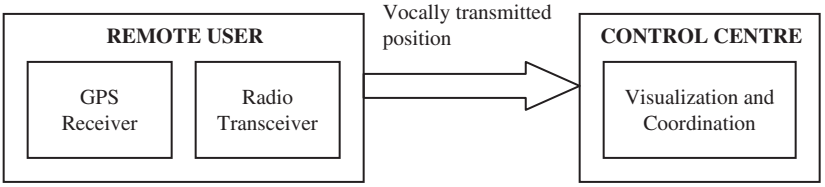

Fig. 5. System for teams management in use at the present by the CNSAS.

cost-effective solution if compared to other technical choices (i.e. with respect to satellite communication).
- The rescuers' equipment must be portable and ruggedized since it has to be used in hostile environments;
- The operation coordinator has to be able to send back waypoint or text information to each rescuer.

On the basis of such general requirements, the POP-ART prototype architecture will follow the scheme reported in Fig. 6. This basic architecture has been already presented in [1].

The POP-ART system architecture is based on the Galileo Local Element concept, i.e. a fixed system infrastructure foreseen in the Galileo architecture which will enable a centralized service provider to deliver a Galileo local positioning services within a limited, or local, geographic area to remote terminals connected through a wireless communication technology.

The idea of the POP-ART project is to equip the rescuers with Remote Terminals (RTs) that will be a portable devices able to communicate with Operation Coordinator (OC) for obtaining POP-ART precise positioning (performed thanks to the integration of EGNOS corrections) and additional location based services. The OC will be fixed station supporting the operation manager, who is the person in charge to control and manage the work force employed in the field during mission. Moreover different OCs can share useful data and information through a Remote Data Center (RDC).

The RT is composed by a Remote Terminal Device (RTD) which performs the main RT functionalities and a Personal Digital Assistant (PDA) that implement the Man Machine Interface (MMI). The RTD is endowed with a GPS chipset able to download raw GPS measures and a communication unit for the communications toward the OC. Within the POP-ART system the selected wireless communication technologies are primarily the VHF channel that is available and reliable in mountain environment, and additionally the GPRS channel, employed as backup channel.

Due to the hostile work conditions of the rescuers, the RT must be rugged in order to resist to shocks, cold temperature, water and so on. Moreover, due to its mobile nature, the RT power consumption has to be optimized.

The OC is composed by the Search and Rescue Network Precise Positioning (SAR-NPP) and the Search and Rescue Mission Control Center (SAR-MCC). The SAR-MCC is in charge to provide the graphical interface and the OC location based services as well as the interfaces between the OC and the RDC. The SAR-NPP has to manage the data communications toward the RTs by means of a communication unit and to provide the precise positioning thanks to its GPS/EGNOS professional receiver. This receiver is able to directly download EGNOS correction by the antenna or alternatively to receive the augmentation data through the internet ESA service, named Signal in Space through interNeT (SISNeT). In this way the EGNOS data should be always available at the OC side.

As sketched above, the main feature of the POP-ART system is the rescuers precise positioning demanded to the OC. The OC matches the RT data received through the active communication channel (usually VHF channel) with its own

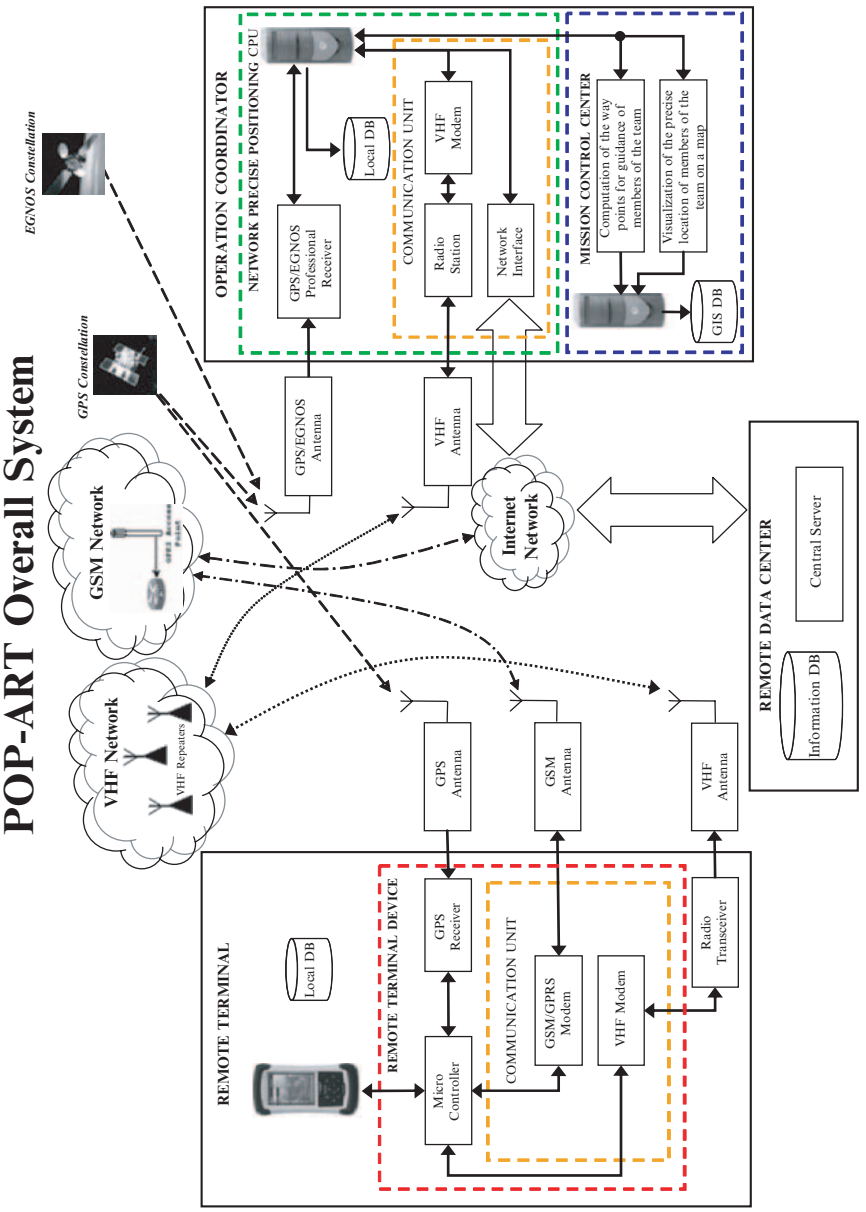

Fig. 6. The POP-ART detailed architectural design.

GNSS information, and computes the precise positioning employing EGNOS data. Then the position is sent back to the RT and immediately visualized on a digital map at the OC side. Of course also the RT, if the PDA is connected, can visualize the same position on a map.

The architecture described above permits at the operation manager level to have a real time and accurate monitoring of the rescuers employed in the field; in fact the Position Velocity Time (PVT) computation performed at the OC side is accurate (under 2 m of error, as described in Section 4) and reliable due to the continuous availability of EGNOS correction. Moreover the automatic data exchange cancels the possible mistakes causes in the rescuers position recording due to misunderstanding in the vocal communications or mistakes in recording phase.

It has to be remarked that mass-market GPS handsets enabled to apply EGNOS corrections are currently available. But the EGNOS signal is broadcast by geostationary satellites from the south direction with respect to the Alps. In Europe such satellites are seen with an elevation angle that can cause visibility problem, especially in mountain environment and, in particular, in north slopes (e.g. in the western Alps EGNOS geostationary satellite Inmarsat 3 F2, AOR-E has an elevation angle of about 30°, which could be not high enough). As the visibility of the EGNOS satellites is not assured, a network-based approach has to be followed in order to guarantee the availability, reliability and accuracy of the positioning service.

Moreover the EGNOS corrections must be continuously downloaded due to restricted validity time and applicability conditions, causing waste of power supply that is an important problem for portable devices.

The POP-ART architecture allows to rely on EGNOS features in every kind of environment, assuring also a limited (and adjustable) power consumption at the RT level.

On the top of the technical features, it is important to highlight that POP-ART allows the rescuers to receive ad-hoc LBS (Location Based Services). For example, the operation manager, can send information about point of interest such as helicopter landing or refuge, when requested.

4 Expected Performance

Regarding the accuracy that can be potentially achieved by POP-ART through the network-assisted Local Element approach; many tests have been conducted on the precise positioning using EGNOS and on the reliability of the communication infrastructure.

Such tests have been conducted under the following constraints:

- PVT computed at the network level employing raw GPS pseudorange measurements made available by standard GPS chipset (e.g. SiRF Star III) at the remote terminal level;
- EGNOS corrections downloaded from an EGNOS reference station that employs a professional GPS/EGNOS receiver and EGNOS corrections taken from the server of the SISNeT service managed by ESA;
- Static and dynamic conditions.

4.1 Static Test

Hereafter some results of a static test of about 12 hours are reported. The test has been leaded in Torino where the EGNOS satellites have an elevation angle of about 32 degrees.

Figure 7 shows the 3D positioning error with and without EGNOS corrections as well as the time percentage in which the horizontal error is lower than 2m varying the masking angle (and so varying the DOP). It has to be noted that for all the masking angles the EGNOS corrections are applied even if the EGNOS satellite results to be not in view at the terminal level. In fact, the PVT is computed at the network level where the corrections are always available as previously explained in Section 3.

4.2 Dynamic Test

Figure 8 shows the results of a test conduced in dynamic conditions within a real mountain environment in Entracque (Italy).

Such tests are needed in order to deeply understand the operational problems of non static users and of course to identify critical points, due to the hostile environment (e.g. signal availability in forests or in mountain canyons).

The selected test area is covered by the GSM service but do not give the possibility to have a stable GPRS availability, on the other hand there is a good VHF coverage.

In the Figure a specific path followed an ISMB operator has been highlighted. In such a situation the position was computed in Torino (80 km apart from Entracque) using EGNOS corrections. The rwa data where sent the VHF infrastructure. The reached accuracy demonstrates the capabilities of such a system, which relies on the integrity of the communication channel and the correct data matching between the data coming from the remote User Terminal and the data provided by Local Element.

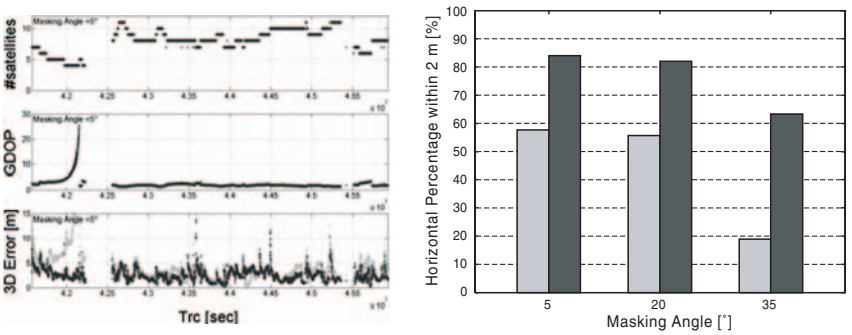

Fig. 7. Left hand-side: Comparison of the 3D positioning errors with (black) and without (grey) EGNOS corrections in the system. Right hand-side: Percentage of computed positions horizontal errors within 2 meters for different masking angles. Measurements without EGNOS corrections appear in grey while with EGNOS in black.

Fig. 8. Dynamic test result. The bold line represents the track of a rescuer equipped with the ISMB test prototype. This test has been conduced in a mountain environment; in particular in this area there are frequent lacks in the GPRS availability; therefore the main communication channel used for this test is VHF.

5 Development Plan

The POP-ART project has been organized following three main temporal phases (see Fig. 9). Each phase will determine a major milestone, in the project development, corresponding to the logical step of the engineering process:

- **Consolidation phase** will output a clear vision of the requirements of the specific application. As already stated this phase is conducted with a strong support of the user community. The consolidation has been ended in July 2006
- **Implementation phase** will realize a prototype of the system in all his aspects: the hardware integrated VHF/GPS/GPRS terminal, the Operations Coordination Centre, the operational software and the core of the complete service;
- **Technology transfer phase** which represents the interface towards other potential user communities (e.g. emergency management teams).

One other relevant aspect is that during this phase the steps necessary for the Galileo use will be envisaged in light of the future evolutions of the system.

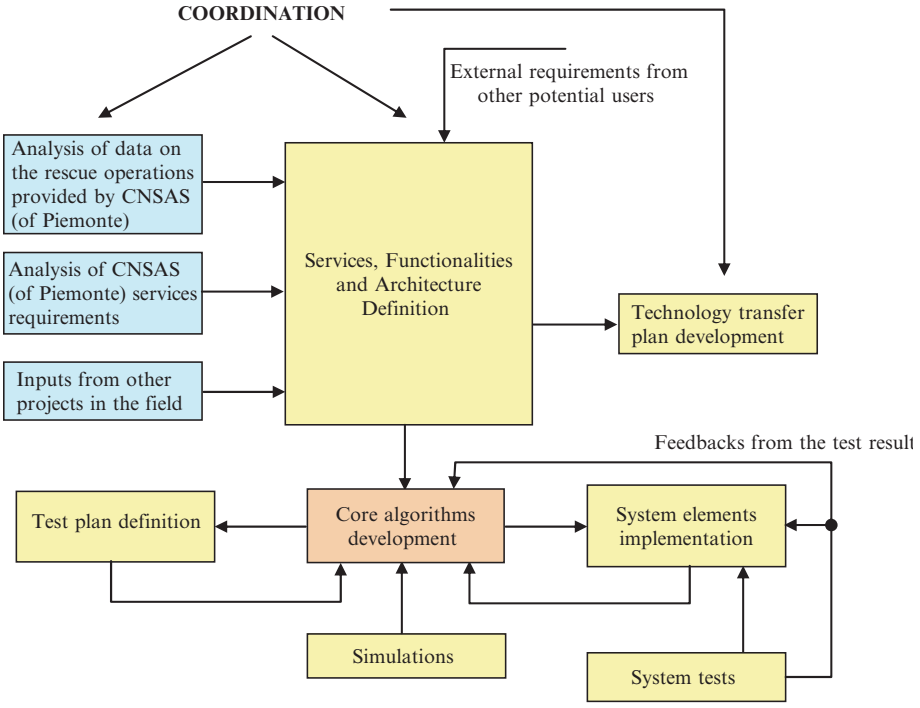

Fig. 9. Development strategy of the POP-ART project.

6 Conclusions and Future Activities

This paper presents the idea and the first results of the POP-ART project. The system adopts EGNOS corrections and VHF communications in the view of realizing a network-based PVT computation. The POP-ART system is designed taking in account the evolution of the system toward Galileo and toward the next generation of COM systems for emergency management like TETRA [6].

The presented system can improve the effectiveness of the interventions of the Alpine Rescue Teams and consequently the safety of the people involved in mountain activities.

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