SAND2007-3301C

Phase II of Rapid Deployment Consequence Monitor Development

Sergey Blagin, Rustem Samigulin, Alexey Veselov, Viktor Ilin
All-Russian Scientific Research Institute of Experimental Physics (VNIIEF), Sarov, Russia

Barry Schoeneman
Sandia National Laboratories, Albuquerque, New Mexico, USA

Abstract

In the case of a radiological dispersal event (as a result of an accident or a terrorist action), emergency responders must assess the hazards in the impacted area to manage the consequences of the event. Tracking the dispersal cloud and making decisions regarding the site assessment, control, mitigation, containment, remediation, and monitoring depend on accurately acquiring dispersal data that was obtained in a rapid manner. Current methods of obtaining this information are labor-intensive, slow, expensive, and risky.

This paper presents the results of the Phase II development of a system for monitoring consequences of man-made accidents or acts of terrorism. The system is capable of performing radiological and climatic monitoring of the environment using the least possible number of sensors installed on each of the sensor node platforms. A base station supports communication with the local sensor node platform digital radio frequency (RF) network. The base station interfaces with a data processing computer that performs data acquisition and radiological and climatic real-time accident site assessment. General concepts of the system's function, as well as the design of its components and laboratory test results are presented. The paper also describes the prospects for further development and applications of the system for monitoring the consequences of a technological accident or a terrorist act in the future.

Purpose and Structure of Rapid Deployment Consequence Monitor

The Rapid Deployment Consequence Monitor (RDCM) system is intended to monitor the consequences of a man-made radiological accident or terrorist act immediately after the act occurs. Sensor nodes are rapidly deployed in and around the center of the contamination and/or destruction area to collect and perform front-end processing. The nodes then transmit data on actual parameters of radiation fields and their changes over time to the data recording station. All of the collected data are displayed on a screen at the Accident Management and Response Center (AMRC) and accumulated in databases for subsequent analysis.

At the core of the RDCM system are compact sensor node platforms (SNP), which are the size of a soccer ball. Each SNP is equipped with a digital wireless communication unit, an antenna, rechargeable power sources, and a built-in Global Positioning System (GPS) receiver. Each SNP has a suite of environmental sensors that measure wind speed and direction as well as air temperature and humidity. In addition, each SNP has specific sensors that measure the radiological parameters of α-activity of respirable aerosols in the atmosphere's surface layer and the β- and γ-radiation backgrounds.

Sandia National Laboratories is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL8500.

Several dozen SNPs could be deployed to the contaminated area using various means of installation. One method involves the radiation survey team members manually placing them at the contamination site (as illustrated in Figure 1); another method involves planes or helicopters with special fixtures deploying the SNPs to the site.

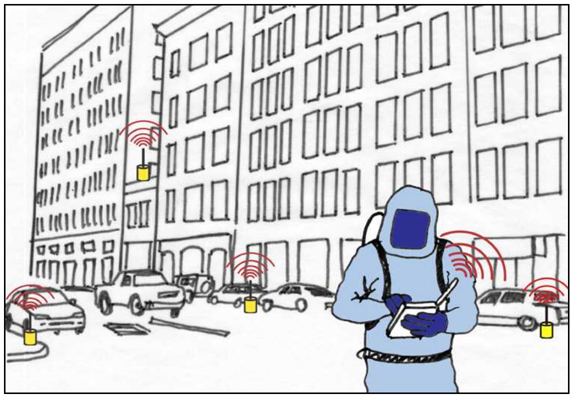

Figure 1. Installation of the SSP

Once the SNPs are deployed to the contamination site, the SNPs collect data regarding the meteorological and radiation field parameters. The SNPs and the base station (BS) at the AMRC form a stand-alone, independent wireless communication network. Since the computers at the AMRC are connected via a wireless data link to each SNP on the ground through the BS, the AMRC receives the data collected by the SNPs in real time via a digital RF channel.

The SNP data are collected in an information database residing on the AMRC computers; this database reflects the situation as it develops at the contamination site. RDCM deployment and operation allows for monitoring the actual state of radiation fields and their changes over time (see Figure 2); it also enables a prediction of how the radiological situation will continue to change in the future.

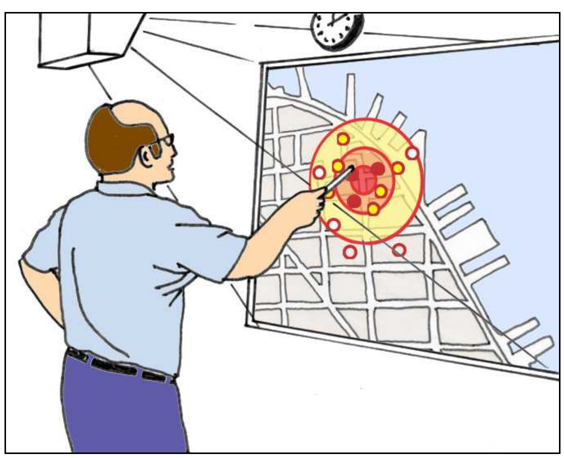

Figure 2. Monitoring of State of Radiological Fields in AMRC

RDCM Development Phases

Development of the RDCM system is being performed as a joint project under a contract between Sandia National Laboratories (SNL) and the Russian Federal Nuclear Center All-Russian Scientific Research Institute of Experimental Physics (RFNC-VNIIEF) as part of the U.S.-Russia Warhead Safety and Security Exchange (WSSX) Agreement. This project is subdivided into four major phases:

a. Phase I: Design Criteria, Design Feasibility, and Task Responsibilities
b. Phase II: Design, Development, Prototyping and Testing of a Base Sensing Node
c. Phase III: Design, Development, Prototyping and Testing of Advanced Sensing Node
d. Phase IV: Optimization, Deployment, Advanced Communication and Integrated Testing

Phase I was completed in 2006, and work on Phase II is currently under way. The result of these activities will be a working prototype of the RDCM system, which will have a basic, simplified design that will include almost all of the sensors from the suite described above; it will not include the α-detector, the β-detector, or a sensor for measuring wind speed and direction. All of these capabilities, however, will be implemented in the advanced version of RDCM that will be developed during Phase III. Phase IV will include full-scale field testing and developmental testing of navigation and information functions of the improved RDCM system version. A description of the basic version of RDCM currently being built by SNL and VNIIEF specialists is provided below.

Purpose and Components of Basic RDCM System Version

The goal of Phase II is to develop and build three working sets of the RDCM system. The first set consists of five SNPs and one BS for arranging a local area network. This set is intended for the initial development and functional testing of the RDCM. The other two sets of the RDCM equipment consist of six SNPs and one BS, which will be used to finalize and complete developmental testing of the RDCM system functions in the laboratory and during field testing at VNIIEF and SNL.

Anywhere from a few to several dozen SNP units can be deployed in the contaminated area by various means. Once deployed, the SNPs begin collecting and storing environmental data. The BS is located remotely at the AMRC and integrates all of the ground-deployed SNPs into a single information network. The BS is a peripheral device connected to a personal computer that is equipped with monitoring software.

Basic RDCM Components and Functional Block Diagram

The basic RDCM components include several types of sensors mounted on SNPs that monitor environmental conditions, including a scintillator-type γ-detector that measures the total cumulative dose, a temperature sensor, and a humidity sensor.

In addition, each SNP has capabilities for ground positioning and supporting a wireless networking protocol with the BS, such as a GPS to determine the exact SNP location in a contaminated area, and an RF-link module to support two-way digital wireless communications and to send accumulated data on the environmental conditions to the AMRC. SNP state-of-health and functionality are provided by the Central Processing Unit, the Power Supply Manager, and a rechargeable battery.

In terms of its functions, the BS is a radio modem that supports the wireless network operations. The BS has a physical connection via the USB 2.0 interface to a personal computer (PC) located at the AMRC. The components of the RDCM, SNP, and BS systems are shown in Figure 3.

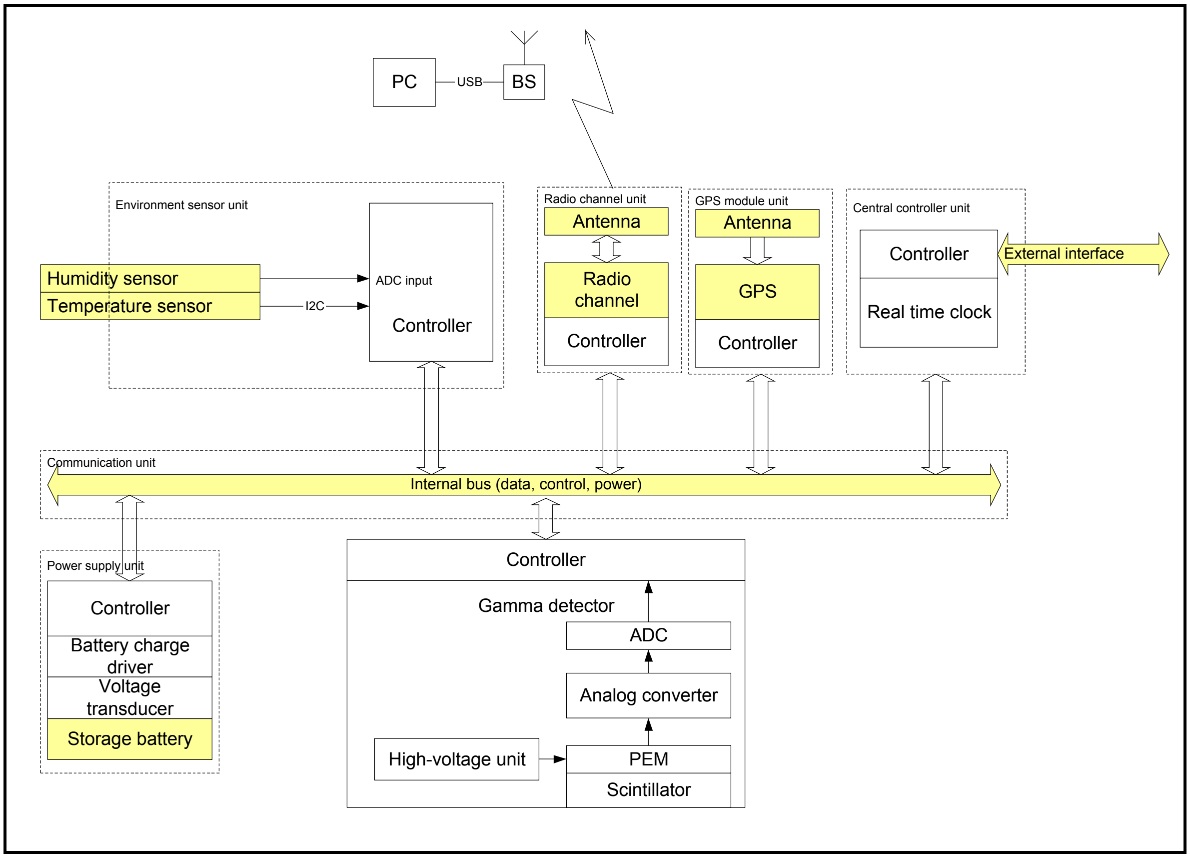

Figure 3. Components of RDCM, SNP, and BS Systems

SNP Design

The basic SNP design is presented in Figure 4. The key element of the design is a housing (13) made of machined aluminum alloy. It provides the required structural stiffness and strength to withstand outside mechanical effects. The scintillator γ-detector consists of an inorganic sodium iodide NaI(Tl) scintillator (2) and photomultiplier (3) protected from light by a cap (1). Electronic circuits responsible for the initial processing of signals from the γ-detector and photomultiplier's high-voltage power supply source are located on a board (6). A module for converting analog γ-detector signals into a digital code for subsequent processing and transmission to the user is executed as circuitry mounted on a board (4).

Temperature and humidity sensors are located on a board (5) mounted inside a recess area on the SNP housing. An RF-link digital module based on the AeroComm AC4790-200M transceiver is located on a circuit board (11) and has an external antenna (7). The GPS module for SNP positioning on the ground is placed under a cover (8). The Central Processing Unit that controls all of the SNP components and Power Supply Manager are located on a board (10). Rechargeable battery (12) provides power to the SNP electronic circuits. A protected electrical multi-pin connector (9) on the surface of the housing (13) is used to plug in the external computer to set the SNP operation modes, perform troubleshooting, and check the rechargeable battery status.

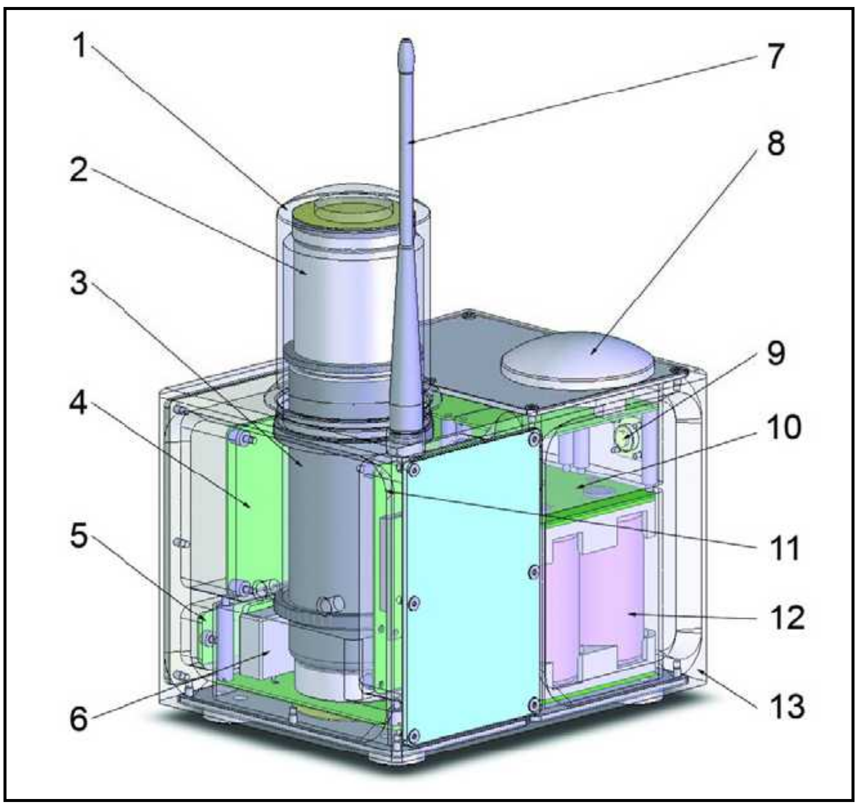

Figure 4. Basic SNP Design

BS Design

The design of the RDCM BS is shown in Figure 5. In terms of its functions, the Base Station is a radio modem located in the housing (1) made of machined aluminum alloy. A board (2) accommodates a wireless digital communication channel based on the AeroComm AC4790-200M transceiver (6) and circuits that adapt the RF module data bus to the USB 2.0 standard. BS power is supplied through a multi-pin connector (3), and a PC is connected to BS via a standard cord through a connector (4). BS RF-signal is broadcast through an antenna (5).

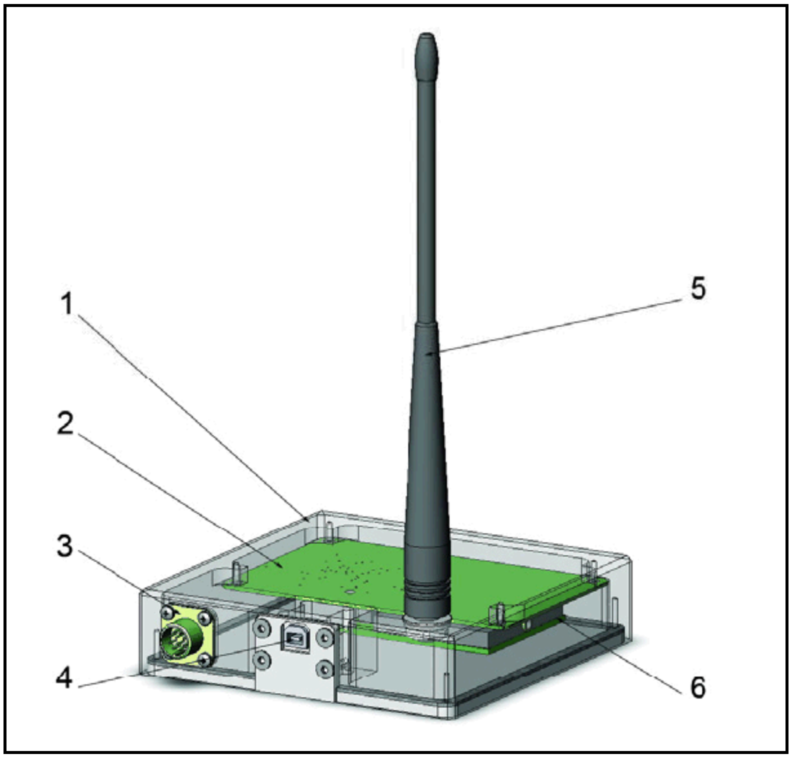

Figure 5. BS Design

Software for Personal Computer

RDCM SNP data are received in real time on a PC at the AMRC. The SNP data packet contains service information, sensor readings, module GPS coordinates, readings from additional sensors, the time at which the data were recorded, and a digital signature of the data packet.

The PC software is capable of plotting the coordinates of each SNP on a map using the GPS data. The software creates a local map of radiological contamination and its distribution in the area using knowledge of the radiation background level at the SNP locations and mathematical interpolation and approximation algorithms.

Data analysis allows for assessment of the contamination level at any point on the ground as well as identification of areas with the highest and lowest contamination levels. Data on the contamination level, temperature, and humidity continuously arrive in the AMRC from SNPs that operate in a single wireless network space. The local map of the radiological situation is dynamically updated in real time.

The PC software is developed to map the radiological situation in the area and allows for the following:

- each SNP position is displayed on a local map with indication of its coordinates and level of gamma-radiation background
- the map of the current radiological situation is displayed
- the current sensor readings from a specific selected SNP is displayed
- current SNP sensor readings are stored, with the option to review the radiological situation on a map at a later time

All data are stored in a single database and displayed on screen by the PC software. Figure 6 shows the main window of the PC software.

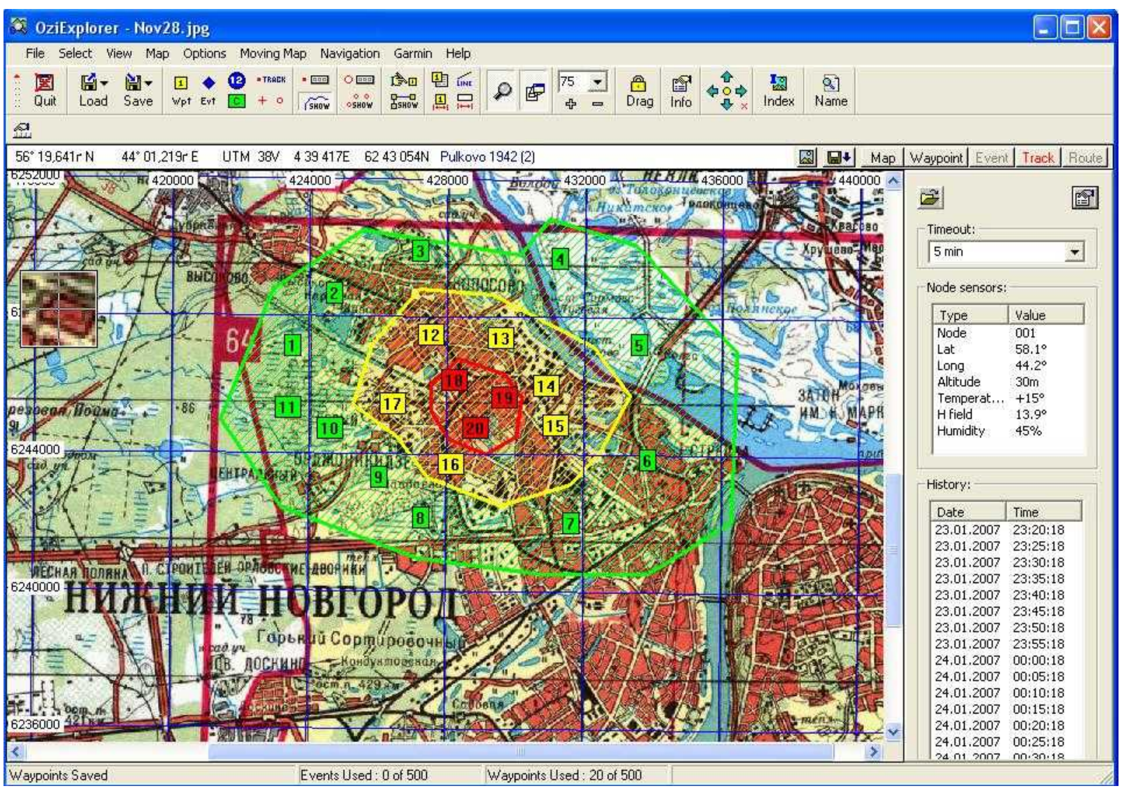

Figure 6. Sample Display of PC Software

Summary

The following results have been accomplished, to date, in the development of the RDCM system:

Phase I

- Work has been completed on the development of the RDCM conceptual design and evaluation of the technical feasibility of implementing the RDCM system in accordance with previously developed technical requirements.

Phase II

- Detailed technical requirements for each of the RDCM system components were developed.
- Market analysis of commercially available electronic components for the RDCM system was performed and requisite components in requisite quantities were purchased.
- A complete set of design documentation that can be used for making small quantities of the RDCM systems was issued.
- A trial system set consisting of five SNPs and one BS for laboratory and field testing and functional demonstrations has been manufactured.
- Preliminary lab tests of the system functionality were performed.

Phase II is scheduled to be completed by the end of 2007. All scientific and technical experience gained by the SNL and VNIIEF specialists in the course of performing this project will be utilized to develop, build, and test an improved version of the RDCM system during Phase III in 2008.