The Development of an Integrated Site System for the detection of illicit trafficking of radioactive and nuclear materials

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ABSTRACT

The Global Partnership is an international collaboration of some 23 states in the EU, with a portfolio of projects aimed at improving national and global security. The partnership works to reduce threats from terrorism and Weapons of Mass Destruction (WMD) across the Russian Federation and the Former Soviet Union (FSU) countries. Efforts are currently being focussed on

- Enhancing nuclear security of materials and facilities in the FSU
- Assisting Russia in destroying its chemical weapons in a safe and environmentally sound way
- Providing safe and secure management for irradiated nuclear fuel assemblies at Andreeva Bay
- Working to close the remaining weapons-grade plutonium producing reactors in Russia and the safe and irreversible shutdown of the BN-350 plutonium breeder reactor at Aktau, Kazakhstan.

Project Services provides the project management for the nuclear security projects portfolio of the Global Partnership, one of six work areas within the nuclear programme, covering:

- Preventing sabotage and theft of radioactive materials
- Reducing vulnerability to and consequences of terrorist activity, which has risen in priority in recent years due to the global situation
- Promoting sustainability of security enhancements to ensure long-term effectiveness.

Within the UK, Project Services has designed, installed and commissioned a number of radiation detection systems to monitor vehicles and personnel movements at the entry and exit points for a major Nuclear Licensed site. All points of entry/exit are covered by radiation detection equipment to detect unusual movements of radioactive or special nuclear material.

The system designs were optimised to meet the specific requirements for operation on a nuclear facility and what is now also a major construction and decommissioning site. This has meant that the raising of 'innocent' alarms due to the movement of construction and demolition materials, and the occurrence of false alarms has been a major consideration in the selection and design of the installed equipment.

Systems from a number of different manufacturers have been selected as the most appropriate and all radiation detection portals have been interfaced together, along with access control systems, turnstiles and automatic number plate recognition technology to provide a fully integrated site-wide system that provides real-time monitoring of the vehicle and pedestrian traffic through the access points to the facility.

The equipment is operational 24/7/365 and alerts the site Guard Force who then isolate the vehicle or person for further investigation. Response procedures to be followed after the triggering of an alarm have been developed in collaboration with the Guard Force and other responders from the site operational teams (e.g. security, health physics). These procedures include confirmation of the presence of radioactive materials (essentially confirming the alarm as genuine), through to barriering-off of identified vehicles (for dose uptake protection), isolation and characterisation of any suspect materials to permit safe and secure recovery operations to be undertaken.

Additionally, a materials characterisation, recovery and disposal service is provided to the UK Home Office and Her Majesty's Revenue and Customs (HMRC) to support similar operations at points of entry into the UK. At these ports and airports, installed radiation detectors scan passengers, vehicles, freight and parcel-post entering the UK. Following an alarm and initial investigations by HMRC, quick response teams from Project Services are available to provide radioisotope identification and activity quantification measurements using state of the art radiometric equipment, permitting any suspect materials to be recovered and either repatriated or disposed of appropriately.

This paper describes the processes that were followed to determine the most appropriate detection equipment for use by the site and how these systems were integrated together to form a single site-wide security system. Procedures for response to facility access point alarms including confirmation of real events, characterisation and recovery of discovered materials are considered.

Market Assessment

The fundamental principle for the provision of access point monitoring systems was that, wherever possible, commercially available equipment was used. This offered a number of benefits to the customer, including the known costs of the systems (compared to the potentially unknown costs of subsidising a research and development programme) and minimisation of risk associated with system operation, performance and support.

At the initiation of the project there were no approved national or international standards that could be used to determine the requirements specification for these detection systems. The IAEA "functional requirements for border monitoring" specification was at an early draft and standards from the US were not directly applicable to use on the selected reprocessing facility.

In order to address these deficiencies, Project Services worked with technical input from IAEA personnel and the UK Government's technical experts to draw up a detailed requirements database that could be used to assess commercial offerings from a variety of suppliers in the marketplace. Compliance tables were then produced and issued to selected instrumentation suppliers for them to detail their offerings, without knowledge of the end customer or detailed performance specifications as this was deemed to be of a sensitive nature. Selected suppliers were then invited to a "Bidders Conference" held at the facility where they were able to visit the potential installation locations and question security and operations experts regarding the requirements and overall concepts.

Project Services then operated a commercial tendering function to issue Invitation to Tenders (ITTs), progress technical queries and eventually select the most appropriate systems for deployment at the facility.

Following a second tendering process, Project Services was then awarded the contract to supply, integrate, install and commission the various systems that were required to meet the facility security requirements.

The Systems

Each entry or exit point around the facility perimeter is equipped with radiation detection equipment to check for attempts (either deliberate or accidental) to move radioactive materials across the facility perimeter. Both inbound and outbound traffic streams are monitored to detect attempts to remove radioactive material from the facility, either for theft or for publicity purposes, or for attempts to introduce materials onto the facility as part of a radiological dispersion device (or again as a publicity stunt).

The facility has significant traffic levels for both vehicular and pedestrian traffic. Approximately 4000 vehicles pass through the most utilised access point each day with traffic flows reaching peak levels at in muster and out muster times during the day. These high traffic levels have required modification to existing systems in order to minimise disruption to the facility operations.

Figure 1 shows a schematic of the layout of detection systems at a generic gate location, identifying vehicle monitoring systems for inbound and outbound traffic streams, a pedestrian monitor with associated access control turnstile and all necessary CCTV systems for traffic/personnel identification.

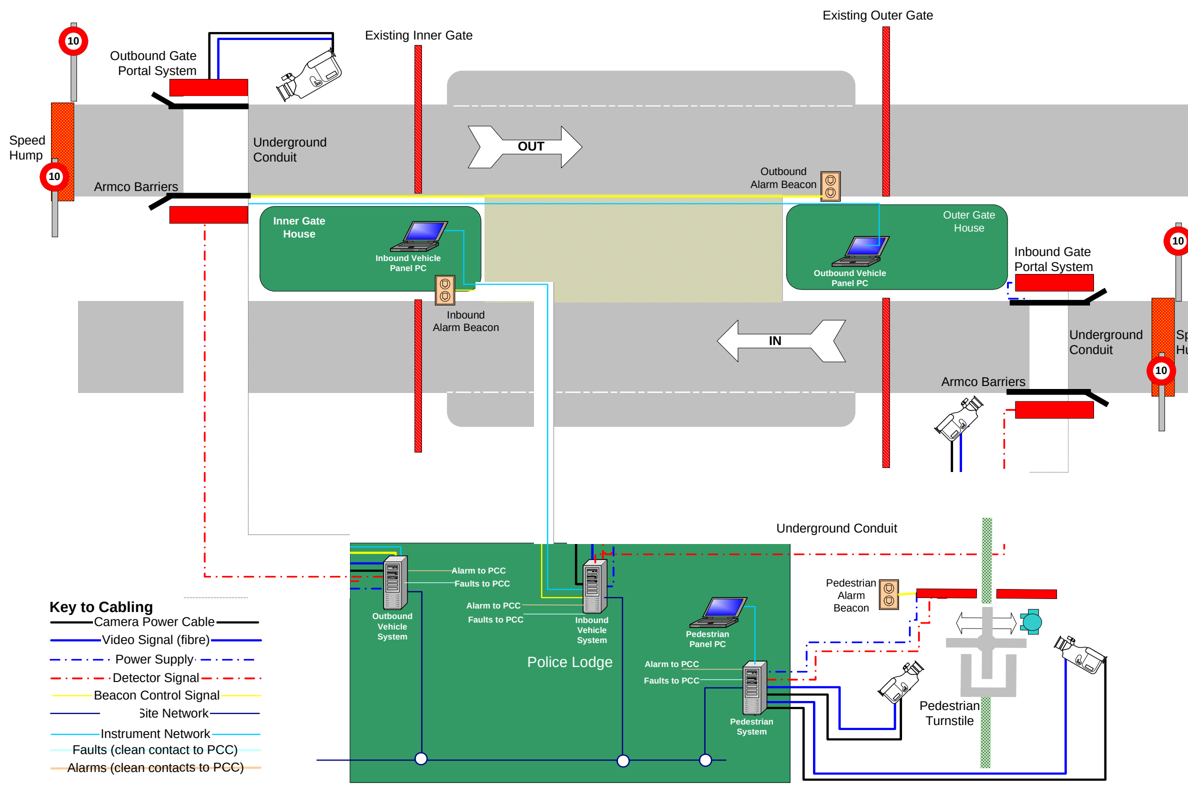

Figure 1: Schematic layout of detection systems at a generic gate layout

Vehicle Traffic

All vehicles entering the facility pass through installed portals to check for any increase in radiation levels as they pass between the detectors. Each portal comprises both neutron and gamma detectors positioned on either side of the traffic lane through the gate.

The detector panels are mounted on 1m tall concrete plinths built on a sizeable concrete raft that has been installed under the roadway. The positioning of the detectors at this height ensures that detection efficiency requirements can be met over a height range of 0m to +4m above ground level, ensuring that all vehicle types envisaged to access the site will be monitored.

Figure 2: Vehicle Monitors during testing

Large volume polyvinyl toluene (PVT) plastic scintillator panels are used to detect any increased gamma radiation. The gamma detection panels comprise two detectors on each side of the roadway positioned one above the other. Each detector is fitted with two photomultiplier tubes, one on the upper surface and the second on the lower surface of the scintillator panel. This design ensures optimum collection of the light pulses (as light losses are minimised) and also enables the two photomultipliers to be operated in coincidence mode, reducing the background noise levels and thereby enhancing the sensitivity of the detection system or providing reduced false alarm rates for a given sensitivity.

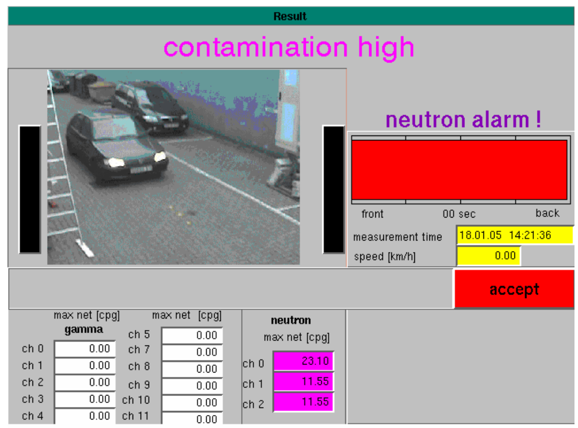

Figure 3: Example vehicle monitor operator interface

The signals from each photomultiplier are also acquired into a number of broad gamma energy regions ranging from very low energy, low energy, medium energy, high energy or very high energy in addition to the full spectrum. Assessment of the relative count rates in these gamma energy regions allows the system to provide an indication of whether the radiation is representative of special nuclear material, medical isotopes, industrial sources or naturally occurring radioactive materials (NORM). Further analysis of the acquired counting rates between each of the four gamma detector panels coupled with infra-red light beam occupancy sensors permits some spatial distribution information to be provided graphically indicating the height of the radiation source within the vehicle, whether it is positioned on the left or right hand side of the vehicle, and the approximate distance from the front of the vehicle.

The adjacent neutron counting sub-system uses high efficiency helium-3 gas proportional counters mounted within polythene moderator assemblies. Again neutron detection panels are located either side of the roadway, each panel containing between 3 and 6 neutron detector tubes depending on the required performance. Unlike the gamma panels, the neutron system comprises single full height assemblies in each portal so although information is provided for left/right position and length from the vehicle front, there is no source height position information provided.

The detection system is also fitted with a dedicated CCTV camera that provides colour still-frame images of all vehicles passing through the portal (See Figure 3). The vehicle image files are automatically assembled into the radiation data files for each vehicle. All data is stored on a local database server within the equipment housing.

In addition to the radiation monitoring equipment, dedicated automatic vehicle number plate recognition (ANPR) cameras (see Figure 4) are positioned to recognise the registration (identification) plates of all vehicles entering or leaving the site. Again, each entry or exit point is fitted with such number plate recognition systems permitting the guard force to maintain databases indicating which vehicles are currently on the site. This approach provides a number of benefits in that records of vehicles remaining on the site can be maintained, vehicular access can be denied if the vehicle is on a "black-list" or temporary access vehicles (deliveries, etc.) that overstay their allocated times can be identified.

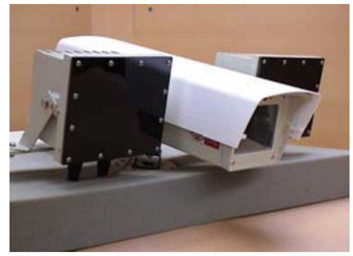

Figure 4: ANPR Cameras

Pedestrian Traffic

In addition to the vehicle access, there is substantial pedestrian traffic through the gates as many employees are required to park their own vehicles off-site and then walk or use public transport to gain access.

All personnel entering or leaving the site must pass through a fully enclosed turnstile system incorporating proximity pass readers, PIN access and radiation monitoring before they are allowed to pass through any access point (see Figure 5).

Figure 5: Pedestrian Monitor during testing

The radiation detection systems again comprise both neutron and gamma detection equipment mounted in custom designed housings that integrate with commercially available access control turnstiles.

Personnel requiring access through the turnstiles are first required to present their site pass to a proximity reader and then enter a personal identification number (PIN) prior to entering the monitoring region. As the person enters the turnstile he interrupts a light beam occupancy sensor and switches the system into monitoring mode. The system checks the gamma and neutron radiation levels against the ambient background to identify whether the person is carrying any radioactive materials.

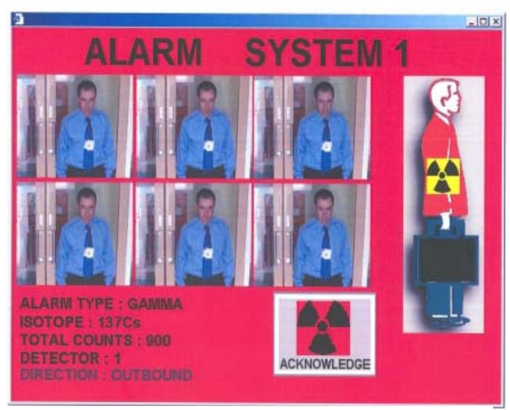

Figure 6: Example pedestrian monitor operator interface

Each detector panel is fitted with two detector systems, one positioned above the other. Each detector system comprises a large caesium iodide scintillation detector providing low resolution gamma spectrometry and two helium-3 gas filled proportional counters mounted within the same module. This dual detector system allows the approximate location of the source identified on the person. The use of low resolution gamma spectrometry permits the system to identify which radionuclides are present by detection of the characteristic gamma ray energies associated with the decay of those radionuclides.

If the measured radiation levels are consistent with the ambient background, the pass is presented correctly, the PIN is entered correctly and that person is authorised (in the central site security database) to pass through the turnstile the system unlocks the rotor to allow him/her to pass. If, however, high radiation levels are detected then the turnstile is locked and an alarm generated to the Guard Force. As with the vehicle systems, the pedestrian system includes a combined colour/infra-red camera to capture a number of images of the person as he presents his pass, enters the PIN and is monitored by the system. These images are stored along with the radiation measurement data within a dedicated database server.

Data Processing and Response

The radiation data and images from the pedestrian and vehicle monitoring systems, and the images and registration plate identifications from the ANPR system are stored in dedicated database systems local to each gate. This provides a full log of all occupancies of the systems, both non alarm and in alarm conditions. For each system, any data flagged as an alarm is also transmitted over dedicated network infrastructure to a central database held under the control of the guard force.

Each guardhouse is equipped with an audio-visual annunciator panel that attracts the attention of the guard, identifying which system is in alarm. A series of touch screen displays within the guardhouse then permits the guard to investigate the alarm, providing details of radiation levels, which radionuclide is considered present, location of the source on the person or in the vehicle, etc. The guard is then permitted to enter details of any investigation and either accept or cancel the alarm.

Following a confirmed alarm the guard force provides secondary monitoring of the vehicle or person using handheld radiation monitoring equipment. Initial investigations are performed using handheld radioisotope identifiers that both confirm the alarm and also provide more information regarding the position and type of radionuclide(s) involved. The systems also display gamma ray dose rate and neutron count rate so that the operator can determine whether it is safe to approach the person, vehicle or item under investigation. Alarms can be set so that the operator does not have to interpret the dose rate data (or even review the data) as he approaches the potential radiation source.

The handheld identifier systems provide a low resolution gamma ray energy spectrum that is automatically analysed to determine which radionuclides are present, listing the identified radionuclides and the category of materials they belong to (Medical, Industrial, Nuclear or Naturally Occurring) allowing the guards to discriminate between innocent and suspicious alarms.

Once the alarm has been confirmed, more in-depth follow up investigations by trained health physics and/or specialist radiometric physics personnel are performed in order to more accurately characterise the identified materials. These investigations use state of the art electrically cooled (and portable) high resolution gamma spectrometers that are capable of distinguishing between radionuclides having similar gamma ray energies (for example Ba-133 could be used to mask the presence of plutonium by virtue of their similar gamma ray spectra, particularly when viewed using a low resolution gamma spectroscopy system). The data acquired is analysed by the firmware built into the spectrometer to provide local information, however, a reach-back service is provided where the acquired data can be transferred over a secure network for off-line analysis by a Project Services team of radiometric physics specialists.

Figure 7: Follow up investigations

This in-depth approach to response provides a number of operational benefits, particularly in the speed in which alarms can be confirmed by the local guard force, thereby minimising the delays to innocent or false alarms, and the provision of a staged escalation of analyses depending upon the data acquired at each stage (allowing optimum use of more specialist personnel).

All data acquired through the installed systems or through manual investigations is date and time stamped and downloaded from the systems onto a central data server. Access controls are in place to prevent the manipulation of data once it has been logged into the databases so that it is admissible as evidence should an alarm incident lead to disciplinary procedures or criminal prosecution in more serious circumstances.

Figure 8: Dose rate map overlay projected onto target vehicle

Summary

The system described forms an integrated facility access point defence against unauthorised transportation of radioactive materials across a site boundary. Both pedestrian and vehicular traffic streams are subject to 100% monitoring as they enter and exit from the site. Project Services has worked with a number of instrument manufacturers to ensure that the supplied systems are modified and optimised for use on the specific site, including enhancements to performance, ability to monitor higher traffic speeds and the integration of the radiation detection systems into other non-radiometric access control systems such as turnstiles, proximity readers, access control databases, etc.

Similarly, Project Services has worked closely with the guard force for the installation to develop response plans that are specifically tailored for the facility, ensuring minimal disruption to the site operations.

The example shows how such systems and processes could be offered to specific sites, country borders, national and international events, etc. to form a defence against trafficking of radioactive materials, from concept design through procurement, installation, commissioning, operation and subsequent response to any alarms that are generated.