Development of a Portable Monitor

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Abstract
Constellation Technology recently marketed a portable portal monitor for use by emergency response personnel and others needing a temporary means to screen people for contamination. The monitor consists of two-detector panels and frame hardware to hold the panels erect. Parts are designed so that one person can move and set up the monitor relatively quickly. The presentation traces the development of the monitor from the original prototype delivered to Health Canada. Detector, electronics, and firmware selections are discussed on a basis of building a practical and sensitive instrument that meets customer needs. Testing, both environmental and radionuclide detection, was a key part of the development process. Decisions during the design process necessarily involve cost and performance tradeoffs. It is essential that these tradeoffs impact the monitor's performance as little as possible while keeping the cost within reason. Test results show the performance of the "final" product.

Introduction
Our "Portable Personnel Portal Monitor", later shortened to the "P3" monitor was developed in response to a request from Health Canada for a truly portable system for screening potentially contaminated personnel. The monitors were to be set up quickly, possibly outdoors, and provide a "go-no go" indication in a likely chaotic situation. Detection was to cover a broad spectrum of possible contaminants, including special nuclear materials, but most likely fission products such as ^{137}Cs. Operation needed to be simple but the monitor needed to adapt to multiple accident scenarios. The monitor needed to be truly portable -- Health Canada operators expected to hand carry the monitor and transport it without the benefit of material handling equipment. Some other commercial "portable" monitors actually were stationary devices with wheels added; these would be unworkable in the anticipated application. Previous portal monitor development has emphasized detection limits and minimal false alarms over size and weight. "Applications Guides" [1] for monitoring locations using Special Nuclear Materials (SNM) described building the monitor into hardened guard stations. Minimal power usage was never discussed. Our planned application was more likely to be at the edge of an outdoor perimeter near a radiological accident. Our monitors were designed to operate on battery power for a minimum of 24 hours, rechargeable from utility power when available.

Constellation Technology Corporation (Constellation) responded to Health Canada's request with the "P3" monitor. The monitor was designed as a portable device from the outset. We first selected the industry-standard plastic scintillator detectors for their usual advantages: good sensitivity, large size, low cost, and general robustness. Due to the likely outdoor application NaI (Tl), for example, would not survive the expected operating temperature range. NaI (Tl) was also considerably more costly than plastic. Other detectors, such as gas proportional counters, have been used in portal monitors but required a gas supply or other support, making the monitor more cumbersome. Finally, we did not consider neutron detection for this application, so neutron detectors were not included.

It was (is) important to keep the monitor's user interface simple. The planned application involves rapidly screening many personnel at an accident site. A trained health physicist may cover several monitors simultaneously. Accordingly, we wanted multiple alarm indications -- visual, audible, and a remote signal. Unlike many monitor applications, the customer was tolerant of false alarms. An alarm meant that the person in the monitor would be hand "frisked" and a determination of what action to take made on the base of the hand examination. The monitors needed to start up in a pre-set detection mode, as it is not practical to do calibrations and adjustments in the field. Adjustments would be done periodically when the monitors were tested prior to deployment. As discussed below, we built a capability into the monitors to do calibration, testing, and data display by connecting to a laptop running an application code developed for the portal monitor.

The monitor housings were based on "SKB" rifle cases. These inexpensive cases were designed for commercial shipping without overpacking and provided adequate space for the detectors and electronics. The cases were available with wheels for easy transport. All the transport features built into the cases were useful in our portal monitor. When completed, we estimated that the case, detector, and hardware would weigh under 40 lbs., and could be hand carried as required by the customer. Mounting the detector in the case developed through several stages. We had requirements that the detector survive a three foot drop -- from a truck bed to the ground, for example, and survive "normal" air shipment as luggage. There were also some electronic components to be mounted with the detector. The first prototype used cut foam to contain the detector and electronics parts. Foam mounting was seen as expedient and provided thermal insulation. Unfortunately, the foam proved to be short-lived: the heavy plastic scintillator moved as the case was transported, eventually compressing the foam and allowing internal components to move in the case. We started to look for another mounting method. The second detector mounting was an elaborate three-axis spring loaded and rubber bumper design from an engineering consultant. Despite the consultant's previous experience in shock mounting equipment, the new mounting did not survive a single round trip air shipment. Our third mounting -- the one now used -- uses Aeroflex cable mountings to suspend the detector within the case. Cable mounts allow about one inch movement in all axes to cushion impacts but are very resistant to damage. Cost was within reason and the mounts are industry-standard items. Internal electronic components were hard-mounted to the case floor in custom metal boxes.

Mounting user controls and indicators external to the case, where they were convenient to use but vulnerable during shipment, was overcome by supplying screw-down covers for the controls. This protected them and eliminated the need to have any need for the operators to open the case. Since the cases have rainproof seals, never needing to open the cases is a positive feature for an instrument designed to be used outdoors.

Lastly, we examined the mounting of detector panels into a "portal.” Two detector cases were hung from tripods forming a three-foot-wide walkway. This provided detector coverage from mid-calf to neck height for the average person. The user's arms, hands, torso, and most of his leg would pass through the most sensitive detector area, with minimal coverage of the feet. We felt this was acceptable for a portable instrument. The tripods were reinforced to prevent tipping. Engineering the mounting completed a practical go-anywhere instrument. The tripods and miscellaneous parts were packed into a third shipping case. Three people can carry the complete portal monitor. Assembly and disassembly takes about five minutes per monitor. Figure 1 shows the assembled portal monitor.

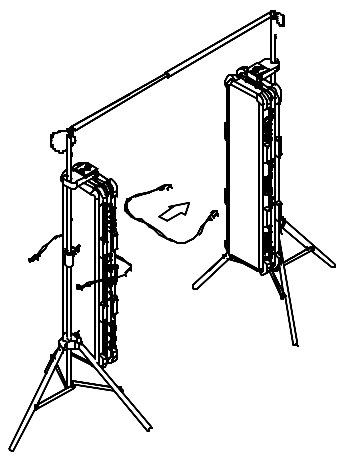

Figure 1 Portable Portal Monitor Set up Ready for Use

User controls are simple. These are located at the top of each case. Controls include power on/off, alarm reset, and an unimplemented custom user control. Power indicators are: green LED, monitor powered; yellow LED, dim: battery charging from utility power / bright; low battery, and red: LED: alarm. An audible alarm "beeps" during alarm conditions. Pressing the button containing the red LED stops the audible alarm. A lower panel contains connections for the laptop serial port, external alarm monitor, and external power connection. An optional multi-segment LED “bargraph” meter displays the logarithm of the gross count rate, providing a continuous indication of detector function.

We omitted several functions that portal monitor users may expect. There is no occupancy sensor to synchronize measurements with traffic through the monitor. This feature proved cumbersome to implement in a field instrument. There is no permanent record of count rate levels in the monitor, although this can be obtained via a connected laptop. Background updating is done manually. Manual background updates were needed because 1) there is no occupancy sensing, and 2) we believed the updating was best left to trained operators, given the uncontrolled conditions prevalent in field operations.

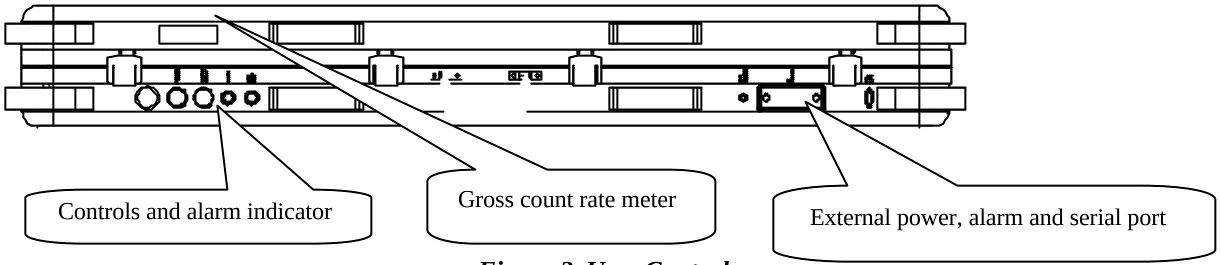

Figure 2 User Controls

Portal Monitor Instrumentation

As noted previously, the portal monitor detects gamma radiation using a pair of plastic scintillators. Light generated in the scintillators is amplified and converted by photomultipliers. Detector data is processed by Constellation's Basic Multichannel Analyzer (BMCA). The BMCA contains a dedicated microprocessor, which provides a complete MCA and additional firmware to implement portal monitor detection algorithms. The BMCA also drives alarms and user controls.

We implemented two detection algorithms in the monitor. A basic "gross count rate" determination detects large sources passing through the monitor. This is similar to that used in most portal monitors. Counts are acquired over one-second intervals. At the end of the interval, the accumulated count is compared with an average "background" to determine if the difference between "current" and "background" rates is statistically significant. The criteria for determining how the counts differ is based on Currie's analysis.[2] This approach has been used for contamination monitoring in earlier monitors and evaluated for detection sensitivity. [3] [4]

The gross count rate is simply the total of all detected gamma rays during a one-second interval:

$$Gross\_Count\_rate = \sum_{k=1}^{1000} S_k \Big/ time$$

For a 1024 channel spectrum where the S_k's are the values stored in the k-th element of the spectrum. Only channels 1 through 1000 are used. Likewise, the sum of the counts in a spectral regions is:

$$Sum_j = \left(\sum_{k=start,j}^{end,j} S_k \right) \qquad Rate_j = \left\lfloor Sum_j \big/ time \right\rfloor$$

Where (start, end) define the j-th region of the spectrum. In this case, the monitor's internal processor will sum the contents of all MCA channels within a specified range.

Spectral region ratios form the second part of the monitor's algorithm. Three ratios defined as:

$$ratio_i = \left[Rate_i \Big/ \sum_{j=1, i\neq j}^{4} Rate_j \right] = \left[Sum_i \, / \sum_{j=1, i\neq j}^{4} Sum_j \right]$$

are computed for user-selected spectral regions of interest. Since the counting time is the same for all rates within a spectrum, the sums may be used directly.

Having defined the gross count and three ratios as the criteria used for detecting alarm conditions, it is necessary to select trip levels for each of these. The selection is based on determining averaged gross count and ratio values by measuring thirty one-second intervals when the monitor is first turned on. The average values and standard deviations of the averages, defined as "background average" and "σ" for each of the gross count and three ratios measured are used to set four alarm levels of "background average + N$\bullet\sigma$". "N" values are selected based on the degree of sensitivity desired vs. the acceptable false alarm rate. "Background average + N$\bullet\sigma$" represents Currie's L_c value, the alarm level. The value of "N" corresponds to a position in the cumulative probability distribution of measured values. The user selects "N" to achieve the best possible sensitivity with an acceptable false alarm rate. The value of "N" is set by default to n = 5 if there is no user input.

The monitor computes alarm levels as:

The average of x: $\bar{x} = (1/M) \bullet \sum_{j=1}^{M} x_j$ For a set of *M* data

Standard deviation: $s_x = \sqrt{\sum_{j=1}^{M} (\bar{x} - x_j)^2 / (M-1)}$ For a set of *M* data

Here, "x" represents either the gross count rate or a ratio.

It may be noted here that we chose to compute an average from a series of actual measurements. At least one other method of computing averages based on the square root of the average count was considered and rejected as less reliable, because direct measurements included systematic errors in addition to those based on counting statistics.

The portal monitor alarms when *one or more* of the ratios *or* the gross count exceeds its respective trip level. Trip levels are determined by:

$$gross\_rate\_alarm\_level = gross\_count\_rate_{background} + n \bullet s_{gross\_count\_rate}$$

For the ratios: $ratio\_alarm\_level_i = ratio_{background,i} + n \bullet s_{ratio,i}$ where the "i's" refer to ratios 1 through 3.

When the monitor is tested with sources, as was done by the Health Canada customer, the source strength produces a count rate or ratio in the monitor equal to Currie's L_d. The source strength generating, on an average, L_d counts (or ratio) is selected so that a series of measurements of this source will result is some fraction of measurements above the L_c trip level. The user selects L_d, usually by measuring a group of sources having different activities, to find the smallest activity that provides an acceptable fraction of alarms vs. passages through the monitor. This concept is discussed in testing procedures.

Regions of interest 1, 2, and 3 are chosen based on the primary gamma ray energies emitted by sources the user would expect to encounter. Region 4 is set to whatever remains between the highest channel in the first three regions and the "top" of the spectrum, channel 1023. Standard practice does not use overlapping regions, although the monitor will function with overlapping regions. It is not necessary to set the regions to cover all channels in the spectrum. Plastic scintillator radiation detectors used in the monitor do not detect the "full energy peaks" of radionuclides of interest, but rather detect the "Compton shoulder" caused by the emitted gamma rays. The monitor can detect ^{241}Am emission at 59.5 keV. The Compton edge for 59.5 keV results in very low detected signal amplitude. Careful setting of the regions and low-level discriminator was needed to detect ^{241}Am.

The portal monitor updates the background only when the instrument is first started and on command from the serial port (laptop application code). We do not update background values more frequently because the monitor does not contain an "occupancy sensor" to determine when updating would be appropriate and because anticipated operating conditions do not ensure that sources would not be present even if the portal monitor was unoccupied. The user can force background updating, of course, on command. Further reason not to use automatic background updating involves the problem of slowly moving sources. This is of more interest in SNM protection than contamination control. It is possible to move a source slowly towards a portal monitor, causing the background to update to increasing gross count rates and to ratios characteristic of the source. (At least this situation is frequently discussed in published reports on portal monitors. It is implemented in competing portal monitors). To prevent circumventing the monitor in this way the monitor must alarm if the gross rate increases more than "n"-sigma above the background when the monitor was powered up regardless of whether the current gross count is below the current $n \bullet \sigma$ threshold.

This function is implemented in the gross count rate. Gross count rate is continuously examined along with the other ratios. The monitor will alarm if the gross count increases above its trip level.

User Setup and Monitoring Application

A Windows-based application allows the user to configure to portal monitor functions prior to use and to monitor parameters in detail. The application is intended to run on a laptop computer via the serial port on each monitor detector panel. Once set, the monitor saves parameters in nonvolatile memory until they are changed again. User interaction with the application involves several menu screens

Activation of *ROI_Detect* application generates a screen divided into three horizontal sections: the top line, the center section, and the bottom line. The center section allows selection of various modes of the program and parameter changes with buttons labeled Settings, Ratios/Gross Count, Real-Time Levels, View/Export Log, and Port Config/Options. Each screen is described in detail below. The top and bottom lines are the same for all modes and are described here. The top line has two pull-down menus labeled File and Help.

The File menu contains the command Exit.

- Exit — Selecting Exit terminates the program. The P[3] Monitor can continue to operate with the currently defined alarm thresholds.

The Help menu shows an "About this program" screen.

- About — The version of the software release is displayed along with the Constellation e-mail address and telephone number.

The bottom line of the display has three areas showing status of the device. The field in the lower left displays the currently active function of the program. The lower middle area displays the polling status. The lower right area displays indicators associated with alarm status. The lower left area contains status messages relating to the communications (or lack of communication) with the portal monitor and computation errors that could occur during gross count and ratio analysis. Other messages indicate that the regions of interest have been updated, for example. Polling status is also displayed. The application normally requests information from the monitor on a continuous basis.

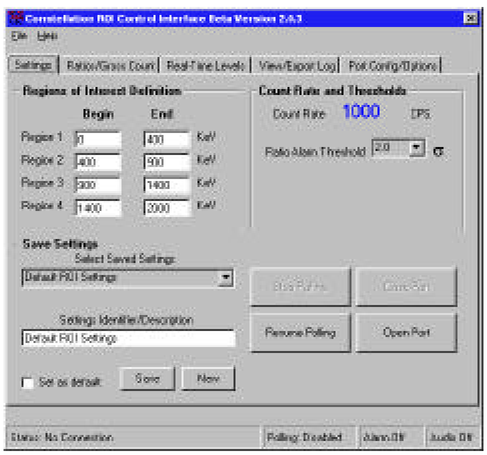

Figure 3 Control Interface, Normal Mode

There are two fields in the lower right that display alarm status. The first field indicates whether the alarm light is on (Alarm On) or off (Alarm Off). The second field indicates whether the integral alarm horn is on (Audio On) or off (Audio Off). Regions of interest may be set and examined in the next screen. Clicking the "Settings" mode button in the top portion of the center section of the screen generates the screen depicted in Figure 4. Selection of each of the eight data fields in the **Regions of Interest Definition** section allows entry of the desired beginning and ending energy levels for each of the four regions of interest. The unit of measure is keV. These values are transmitted to the Measurement Unit immediately after they are changed (as a Begin-End pair). However, the Measurement Unit will not act upon the new values until the initialization sequence on power-up. Therefore, power must be cycled on the Measurement Unit for the changes to take effect. The total current count rate is displayed in counts per second (CPS) in the **Count Rate and Thresholds** section. The desired alarm threshold is entered in the field labeled Ratio Alarm Threshold. The unit of measure is sigma relative to its particular region. This change takes effect immediately. The **Save Settings** section allows a set of parameter definitions to be saved/retrieved by name. The first area is labeled "Select Saved Settings." The list box allows selection of a previously saved set of parameters. The "Settings Identifier/Description" displays the name of the current set of parameters. The "Save" button will save the current set of definitions as the name displayed in the "Settings Identifier/Description" box. The "New" button will allow the addition of a new name for the current definitions. Thus, to save the current definitions without overlaying any previous definitions, click the "New" button, enter the new name, and then click the "Save" button. Placing a check in the "Set as default" checkbox, defines the displayed settings to be the default settings. Toggle the checkbox to set the current settings as the default. Click the "Save" button for the default definition to take effect.

The lower right quadrant of the center section contains four buttons that operate in pairs. The appropriate button of either pair is available at any given time. The other button of each pair is "grayed" and not available. The "Stop Polling" button stops polling (if polling is active). The "Resume Polling" button resumes polling (if polling is inactive).

As the names imply, the "Close Port" and "Open Port" buttons disable/enable the communications port. Note that The "Resume Polling" button automatically opens the port and that the "Stop Polling" button automatically closes the port. Closing the port will also automatically stop polling. However, opening the port does not automatically start polling

Clicking the “Ratios/Gross Count” button in the top portion of the center section of the screen generates the screen depicted in Figure 5:

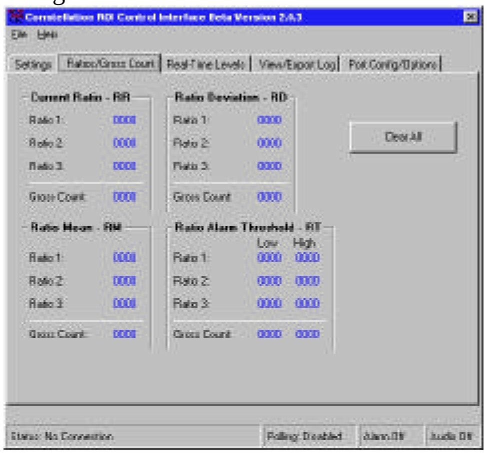

Figure 4 Control Interface, Ratios/Gross Count

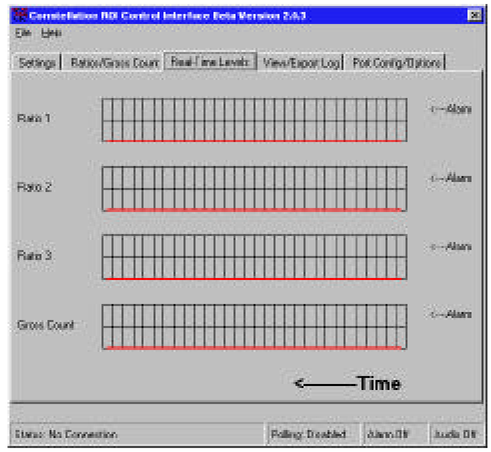

Figure 5 Control Interface, Real-Time Real-Time Levels

This screen displays four sets of current information and one action button. The four sets of displayed data are: current values of the three ratios and the gross count rates, standard deviations for each of these, the average values measured during background data acquisitions, and the alarm threshold “trip levels” that are the sum of the average background value + “$N \bullet \sigma$”. The “Clear All” button refreshes the screen with zeroed values for all of the current data. As real-time data is generated, the screen is repopulated with live data.

Clicking the “Real-Time Levels” button in the top portion of the center section of the screen generates the screen depicted in Figure 6. The center portion of the display graphically shows a real-time plot of the ratios of the current regions of interest and the gross count in a “virtual stripchart.” The passage of radioactive sources through the monitor may be viewed on this screen. Current alarm thresholds for each ratio and the gross count are shown. Each data point represents the results of one polling activity. The vertical scaling of each plot is automatically set such that the upper alarm limit corresponds to the “←Alarm” indicator on the graph. The time scale moves to the left. New data enters on the right of the screen and propagates to the left. An alarm is generated when a ratio goes above the limit.

Clicking the “View/Export Log” button in the top portion of the center section of the screen generates the screen depicted in Figure 7. The window on the left side of the screen contains the list of log files available. The user may select log files to view and select configuration of display and export options for the file. Files may also be renamed and deleted. A “refresh” feature updates the list of available log files.

Clicking the “Port Config/Options” button in the top portion of the center section of the screen generates the screen depicted in Figure 8. This screen is divided into three areas: Port Configuration, General Settings, and Transmit/Receive Activity.

As the name implies, the Port Configuration portion of the screen allows configuration of the communications port. A list box allows selection of the desired port. Radio buttons allow selection of the appropriate configuration for number of bits and even or odd parity. The four buttons on the right hand portion allow the user to open the port, close the port, send a Ping command to test communications, and save the port configuration.

The General Settings portion of the screen allows configuration of the log files. The “Polling Interval” (in milliseconds) defines the polling rate. Select the window and enter the desired interval. The polling activity is displayed in real-time in the Transmit/Receive Activity area of the screen. The “TX/RX Rows” field defines the number of rows to display on the screen. The default is 11 rows, which is the height of the screen display area. Specifying a larger number will generate scroll bars in the display area, allowing more data to be seen. Specifying a smaller number will correspondingly limit the viewable data.

The lower half of the section is dedicated to the transmit/receive activity. As noted above, the transmit/receive activity is displayed in the lower window.

Testing the Portable Portal Monitor

There are an abundance of standards for testing monitor sensitivity to SNM [5] and several for testing specific portal monitor instruments for SNM sensitivity.[6] [7] At least one report examined sensitivities of two portal monitor designs for contamination control.[8]. This latter study was supported by the nuclear power industry, which was more concerned with worker exposure than SNM control. We were fortunate that Health Canada evaluated our portable portal monitor using radionuclide sources appropriate for contamination control.[9] ^{137}Cs was used as the principal test source. Sources of 40 kBq to 2.7 MBq ^{137}Cs and 75 kBq ^{133}Ba were prepared in liquid scintillation containers. Testing protocol:

> *"The sources were carried at mid-torso height or wheeled through on a cart at mid torso height. The pace varied from a normal walking pace to a slow walking pace (1 step per second) to a short pause (up to 10 seconds depending on the activity and whether the alarm sounded on either or both units"*
>
> *"Selected sources were also shielded with ~2cm of tissue equivalent material that simulated muscle tissue to asses the effect of attenuation on the alarm levels"*

"Standard" spectral regions of interest were used: region one: LLD-400 keV, region two: 400-900 keV, region 3: 900-1400 keV, and region 4: > 1400 keV. Background count rates were measured on power-up by the instrument. Background levels were typical of those in a laboratory.

Testing proceeded using a realistic scenario; the "normal pace" described above was used for all tests. The highest activity source caused alarms ~1.5 m from the monitor. Other sources caused alarms when moved through the monitor. Results of the tests are shown in the table below (Table 1 from HMLTD-00-07). Although not stated, we believe the trip levels were set at the default "5-sigma" level. (TEM - tissue equivalent material)

Activities of ^{137}Cs and ^{133}Ba at which the portal monitor system alarmed.

Radionuclide	Activity (kBq)	Alarm Sounded		
		Normal pace	Slow pace	Two second pause
^{137}Cs in vial	40	No	No	No
^{137}Cs in vial	60	No	Sometimes	Yes
^{137}Cs in vial	86	No	Sometimes	Yes
^{137}Cs in vial	126	Sometimes	Yes	Yes
^{137}Cs in vial under TEM	126	No	Sometimes	Yes
^{137}Cs in vial	146	Yes	Yes	Yes
^{137}Cs in vial under TEM	146	Yes	Yes	Yes
^{137}Cs in vial	160	Yes	Yes	Yes
^{137}Cs in vial	2700	Yes	Yes	Yes
^{137}Cs in vial under TEM	2700	Yes	Yes	Yes
^{133}Ba in vial	75	Yes	Yes	Yes

Since the annual recommended maximum ^{137}Cs intake for individuals who are not radiation workers is 150 kBq [10] which is within the range of detection for the portable portal monitor. HML concluded on this basis that the portable portal monitor had adequate sensitivity.

It is of interest to compare these detection levels with those defined for SNM. Fehlau [11] describes the use of ^{137}Cs and ^{133}Ba as alternate test sources for SNM. The monitor must alarm when an equivalent or larger mass is passed through. Wait-in monitors have specific measurement times depending on the monitor. The probability of alarming was stated as "95% confidence that the probability of detection is at least 50%" when operated in a background of 20 μ/hr. These are summarized below:

Alternative Test Sources and Equivalent Amounts of SNM					
Monitor Category	SNM description	SNM material		^{133}Ba or ^{137}Cs equivalent source for testing plastic scintillator detector-based systems	
		Plutonium (low burnup) (g)	Uranium HEU (g)	^{137}Cs (kBq)	^{133}Ba (kBq)
I	Standard Plutonium	1.0	64	185	120
II	Standard Uranium	0.29	10		52
III	Improved Sensitivity	0.08	3		23
IV	High Sensitivity	0.03	1		11
-----	------	2	----		190
-----	------	10	----		470

Sensitivities for the portable portal monitor fall within Fehlau's monitor categories II and I. At the time of publication, he surveyed the market for (stationary) portal monitors and found that:

> *"Many category I or II monitors have been evaluated and are readily available. Several category III monitors have been evaluated, but these have been wait-in rather than walk-through monitors. No monitor has yet achieved Category IV performance in an evaluation, even as a wait-in monitor."*

Since the evaluated monitors were generally large, permanently installed instruments, we believe the response of our portable unit compares favorably.

Conclusion

Portable monitoring systems are important for emergency response activities. With the recent increase in awareness of potential terrorist "dirty bomb" attacks, we expect renewed interest in portable equipment.

Portable equipment must meet different requirements than permanently installed equipment. For example, rapid response may require equipment to be carried in vehicles or commercial aircraft. Material handling equipment may not be available. Constellation's portable portal monitor seeks to address these requirements while maintaining acceptable sensitivity.

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[1] P. Fehlau. "1990 Update for the Applications Guide to Pedestrian SNM Monitors", LA-11971-MS (1990)
[2] L. Currie “Limits for Qualitative Detection and Quantitative Determination” Analytical Chemistry, vol 40, no. 3. PP 586-593 (1968).
[3] L. Johnson, F. Gupta, R. Stevenson, B Rich. "Portal Monitor Evaluation and Test Procedure" EGG-HS-6378 (1983).
[4] M. Georgeson, C. Nichols. "New ICPP Portal Monitor" ENICO-1083 (1981).
[5] For example: "Standard Guide for Laboratory Evaluation of Automatic Pedestrian SNM Monitor Performance" ASTM C1169-97, "Standard Guide to Procedures for Calibrating Automatic pedestrian SNM Monitors " ASTM C1189-95, and "Standard Guide for In-Plant performance Evaluation of Automatic Pedestrian SNM Monitors” ASTM C993-97, all available from the American Society for Testing and Materials, West Conshohocken PA 19428.
[6] P. Fehlau "Calibrating the TSA Systems VM-250 SNM Portal Monitor," LA-11871-M (1990)
[7] P. Fehlau "Calibrating the JOMAR JPM-22 Pedestrian SNM Monitor" LA-11643-M (1989).
[8] L. Johnson, V. Gupta, R. Stevenson, B. Rich. "Portal Monitor Evaluation and Test Procedure" EGG-HS-6378 (1983).
[9] G. Kramer and B. Hauck "The HML's Portable Portal Monitor for the rapid monitoring of potentially exposed large population groups" MHLTD-00-07 (2000).
[10] "Individual monitoring for internal exposure of workers -- replacement of ICRP publication 54" , ICRP publication 78, International Council on Radiation Protection, Oxford, Pergammon Press (1997)
[11] P. Fehlau "1990 Update for the Applications Guide to Pedestrian SNM Monitors" LA11971-MS, table D-1