

U.S. Department of Energy
Office of Nuclear Incident Policy and Cooperation

Radiation Backpack

Operation Manual

August 2019

This work was done by Mission Support and Test Services, LLC, under Contract No. DE-NA0003624 with the U.S. Department of Energy. DOE/NV/03624--0565.

Radiation Backpack Overview

The Radiation Backpack is a high sensitivity gamma and neutron search instrument designed for low profile, large area radiological searches and surveys. Areas where the Radiation Backpack can be used include office buildings, stadiums, warehouses, shipping ports, borders, cargo container ships and Major Public Events. Applications include baseline background surveys, portal monitoring and emergency response. The unit is easy to operate and can be setup in less than 5 minutes.



Radiation Backpack

Specifications

Modular components (detectors, controller, battery)
Velcro attachment points for ease of configuration
Dynamic and Delta Rate Meter data acquisition modes
User programmable via Smart Phone
Calibration with Cs-137 or background
Spectral multi-channel analyzer with 1024 channels
Gamma Detector – Sodium Iodide 1.5" x 2.5" x 8" (3.8 cm x 6.2 cm x 20 cm)
Neutron Detector – Helium-3, 5 each 2" dia x 13" (5 cm x 32 cm) (2.8 atm.)
Operator Interface – earphones, speaker or Smart Phone via Bluetooth wireless
Battery – camcorder type, 6 volts (35+ hours)
Size – 15" x 15" x 8" (45 cm x 20 cm x 45 cm)
Weight – 17 lbs. (7.7 kg)

Step 1: Setup

The Radiation Backpack can be set up and operational in less than 5 minutes.

Insert charged battery in battery holder and connect plug
Push power button 3 sec to turn on detector (will vibrate)
Insert backpack module in to backpack for transport



Radiation Backpack Control Panel

The backpack will go through a startup procedure with voice commands:

“Gemini Search System, number xxx” (where xxx is the unit number)

“Collecting background, please wait”

The unit will collect a pre-set 120 sec gamma background.

“Background complete, normal search mode”

The unit is ready to use.

The Radiation Backpack operates in two modes for the gamma detector - Dynamic and Delta Rate Meter

The Dynamic Mode is the default mode for the gamma detector. The sample rate is pre-set to 3 seconds which is continuously compared to recorded background data in a continuous running analysis. This mode allows the background to be continuously updated to changing environments – i.e. such walking from an asphalt road to a dirt road to a concrete road, while providing the highest sensitivity.

The Dynamic Mode provides a number alarm (Example: Golf 5 or G 5) based on the following algorithm which is derived from the net count rate divided by the background standard deviation. (Note: in order to maintain a low profile in field operations, we have replaced the words Gamma and Neutron with Golf and November)

$$GFIN = \frac{\text{Signal} - \text{Background}}{\text{Background standard deviation}}$$

$$\text{Alarm Level} = 1 + \text{INTEGER}(\text{Log}_2 GFIN)$$

Alarm Algorithm

<u>Example</u>	
Signal	= 400 cps
Background	= 100 cps
Bckgrd Std Dev	= $\sqrt{100} = 10$
Signal – Bckgrd	= 400 – 100 = 300
GFIN	= 300 / 10 = 30
Log₂ (GFIN)	= 4.9 (Round down and add 1)
Alarm	= 5

Alarm Algorithm Example

The Delta Rate Meter Mode can be accessed by pressing the DRM button on the fly-out screen with the voice stating “Locate Search Mode”. The Locate Search Mode has a 1 second sample rate providing a near real time response. The increase in count rates is indicated by a series of audible tones. The higher the count rate, the higher the pitch of the tones. This mode is used to localize radiation hotspots. The operator can return to the “Normal Search Mode” by pressing button on the fly-out screen.

Step 2: Android Phone Monitor

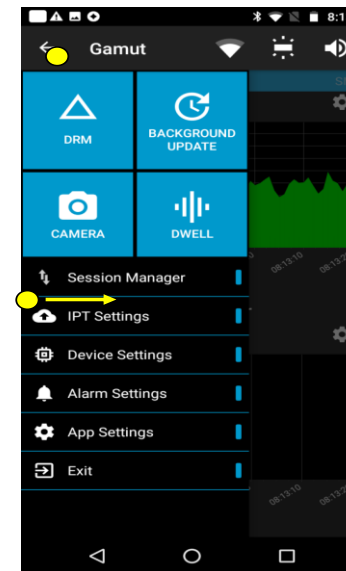
The Radiation Backpack can also be operated with an Android Smart Phone. The Smart Phone option provides the operator similar configuration options as the laptop software but is primarily used as a visual aid. For field operations, the best screen to use is the Plot Mode which shows the alarm levels and strip charts for both the gamma and neutron count rates. The Smart Phone is connected to the backpack via a built in Bluetooth wireless adapter. The display operates in the single touch mode using the stylus. The phone battery lifetime is about 8 hours. Bluetooth range is 20 feet. Turn off screen when not needed to conserve power. This version of Gamut has no telemetry, VOIP or chat mode. It is a standalone version.

To connect Smart Phone to Backpack:

- Power on phone
- Gamut app will start automatically in 1 min
- In 30 seconds, Android home screen
- Fully operational in less than 2 min
- Select “Bluetooth” to connect to sensor (ID is last 3 digits on controller)
- Select Bluetooth ID to connect to system
- Bluetooth Connection Status
 - Turns red when disconnected
 - Turns yellow when connection is interrupted
 - Tap icon to access connection

The four main blue buttons are on the fly-out screen are:

- DRM (Delta Rate Mode)
- Camera (take a photo)
- Dwell (take a dwell spectrum)
- Background Update (update background)



Smart Phone

Set app volume control using icon

Main pages (swipe to switch pages)

- Stage – Main with strips charts and spectrum
- Alarm View – Records alarms since startup

Each alarm record shows:

- Time received (GMT)
- GNR (gamma, neutron, ratio) level
- Gross counts
- Latitude – longitude
- Press and hold an alarm to show location on map

Fly-out Menu (swipe right from left edge, sensor name, Android settings button)

- DRM Mode (toggle)
- Photo
- Dwell measurement (tap and holding strip chart)
- Spectrum is displayed by tapping the alarm overlay on strip chart
- Update Background
- Gamut and Detector Settings

Pinch to zoom on spectra



Main Screen with Gamma and Neutron Strip Charts

Double tap strip chart to open configuration settings screen. To manually set y-axis, uncheck Automatic Scaling Box and then enter values. The chart color can also be changed with orange (default), blue, yellow and green.



Strip Chart Settings

Typical background rates for the gamma (300-400 cps) and neutron (1-2 cps) detectors can be used to monitor proper operation of the detectors.

Step 3: Response Checks

The Radiation Backpack should be checked prior to and following a search operation by placing a gamma source (Cs-137 10 μ Ci/370 kBq) and then a neutron source (Cf-252 10 μ Ci/370 kBq) against the side of the unit for 5 sec. An alarm level of Golf 5 or higher and November 5 or higher should be obtained.

In addition, an automatic operational check is conducted every 15 minutes with the voice stating “**System Status Check, System ok, Normal Search Mode**” or it can be activated at any time by pushing the external button for 1 sec. If a System Check is not received every 15 minutes, the unit may not be operating properly.

Step 4: Shutdown

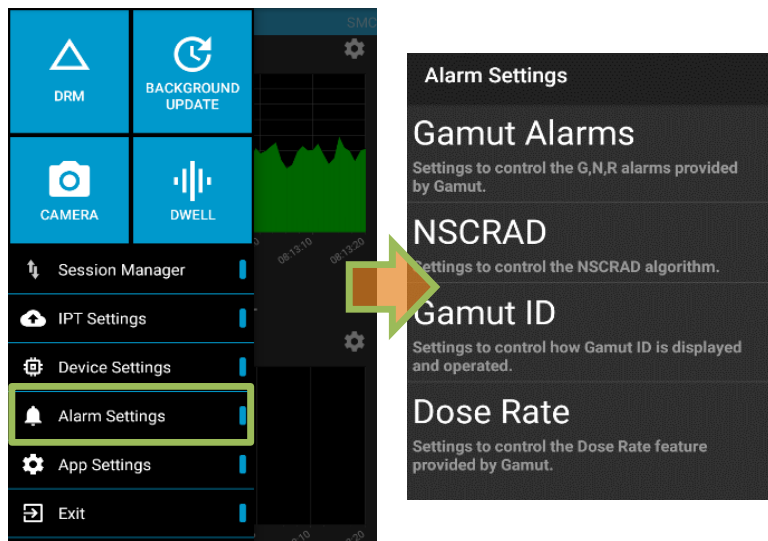
Exit Gamut app and power down phone
Hold power button on sensor for 3 seconds (will vibrate and turn off)

Using Other Android Apps

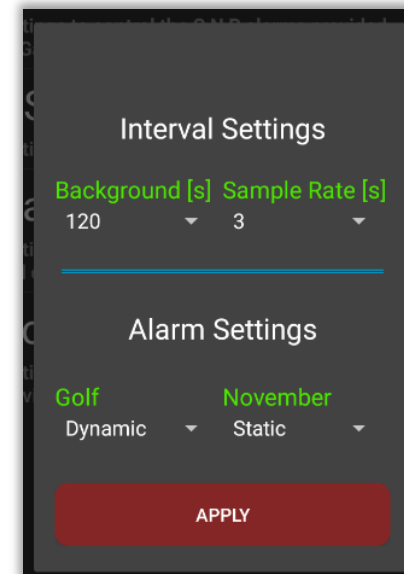
Users can use other Android apps by tapping the Home button
To return to Gamut, tap the Gamut icon on Home screen
Alternately, swipe down from the top of the screen and tap Gamut icon

The default parameter settings are:

Background collection interval - 30-120 s (default 30 s)
Default Alarm timing – Static (DRM) 1 second
Default Alarm timing – Dynamic 3 seconds
Default Alarm Thresholds – Gamma 5, Neutron 4, Ratio 5
Ratio alarm is a measure of man-made sources and is a fixed ratio of the summed counts in the spectral energy windows: 0-1400 keV/1400-3000 keV



Alarm Settings

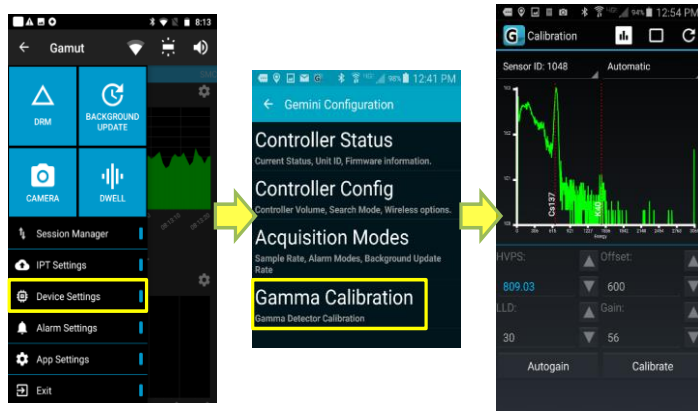


Detector Configuration and Settings Screens

Calibration and Configuration Settings (expert user only)

The Radiation Backpack calibration and default parameters can be adjusted via the Gamut app.

Open fly-out menu by swiping right from left edge
Select Device Settings then Gamma Calibration
Place a Cs-137 source (5-10 μCi) about 1 foot away from gamma detector (adjust distance so count rate is 3-4 times background)
Tap Calibrate and then Save

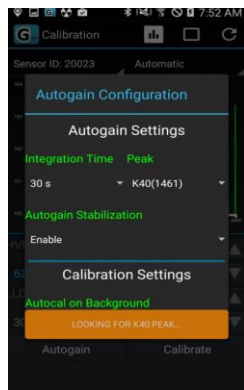


Energy Calibration with Cs-137 or Background

Gain Stabilization

Gain stabilization relies on K-40

- Enable/disable
- Integration time (use longer in low background areas)
- Stabilization peak



Autogain Settings

Isotope Identification

When an alarm is recorded, the isotope ID begins. A billboard will open below strip chart with top 3 results. They are color coded.

- Red – illicit
- Purple – industrial
- Blue – medical
- Green – background

Tapping X will close billboard. Tapping alarm overlay attempts another ID. Tapping spectrum icon opens DwellView with summation spectrum displayed.

Icons on the right are:

- Start dwell
- Clear spectrum
- Transmit spectrum (not on)
- Display options
- Exit DwellView

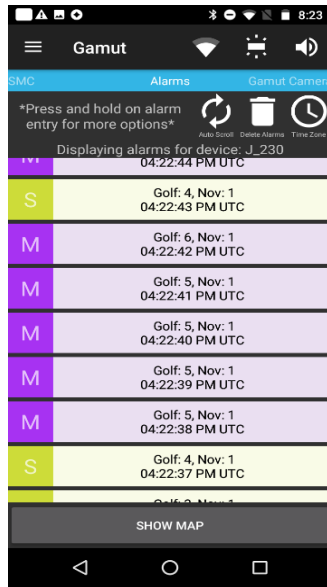


Isotope ID (left) with DwellView (right)

Alarm View

Alarm View screen provides a page with a list of alarms received since app started.

- Tap alarm to show more info
- Press and hold on an alarm to show its location on a map
- Press Analyze to run Identification algorithm



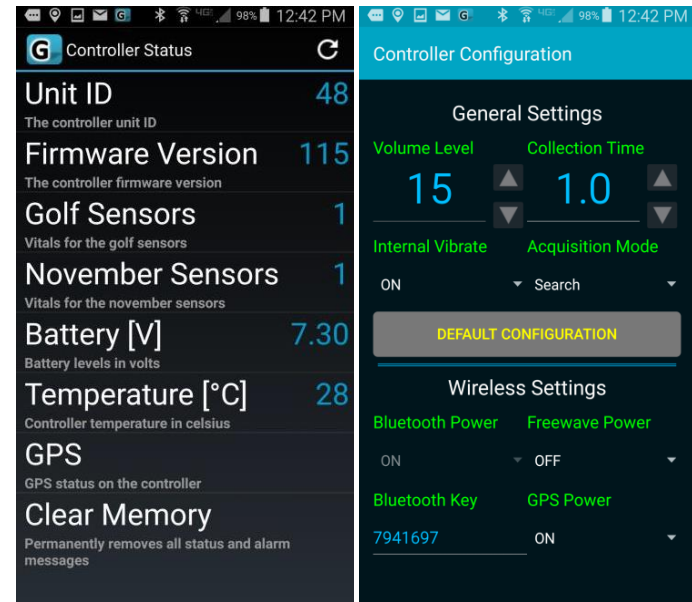
Alarm View

Controller Status

- Unit ID
- Firmware version
- Number of gamma sensors
- Number of neutron sensors
- Battery voltage
- Temperature of the controller
- GPS status

Controller Configuration

- Volume level
- Collection time
- Internal vibrate
- Acquisition mode
- Default configuration
- GPS power



Controller Status (left) and Controller Configuration (right)

Voice Warnings

The backpack will provide the following audible warning if a malfunction occurs:

Low battery – replace battery

No Golf input – gamma detector not working

No November input – neutron detector not working

Maintenance

The Radiation Backpack requires little maintenance. Monthly inspections should include an inspection of unit (cables, connectors, etc.), a review of the kit inventory, a System Check, a review of the background count rates and gamma/neutron alarm verification with sources (see Radiation Backpack Operator Checklist Instructions below). Verify the batteries for the backpack (primary/spare) and the Smart Phone are fully charged. It is also recommended to periodically run the Auto Calibration. Unit should be stored in a cool, dry location.

If the unit is not operating properly, contact the Technical Support listed at the end of this manual.

Radiation Backpack Kit Inventory

Each Backpack Kit contains the following:

Backpack system	Smart phone/charger
Backpack battery/spare	Backpack battery charger
Earphones	International plug adapter kit

Radiation Alarm Log

Date: _____ Time: _____ Location: _____

Radiation Instrument (Make/Model): _____

Alarm Level: _____ Isotope ID: _____

Medical Radioisotope

Name: _____ Phone: _____

Address: _____

Physician: _____ Address: _____

Phone: _____ Treatment Type/Date: _____

Industrial/Naturally Occurring Radioactive Material (NORM)

Name: _____ Phone: _____

Company: _____ Address: _____

Vehicle Make/Model/License No.: _____

Regulatory License #: _____ Device Make/Model: _____

Material listed on manifest: _____

Reporting Format

Line 1: Time _____

Line 2: Location (portal number, etc.) _____

Line 3: Radioisotope _____

Line 4: Data file name for radioisotope identification _____

Line 5: Last name _____

Line 6: First name _____

Line 7: Additional identifying data/information _____

International Radiological TRIAGE Checklist

The following checklist is provided to enable international access to the Department of Energy's (DOE) TRIAGE System for radiological identification of nuclear materials.

1. Assistance can be requested by calling:
 - DOE/NNSA 24-hr Watch Office: + 1 202 586 8100
 - U.S. Department of State 24-hr Operations Center: + 1 202 647 1512
 - IAEA Incident and Emergency Center (IEC) 24-hr: + 43 1 26 32 000
2. The requestor **must** be from the State's (country) IAEA identified Competent Authority or approved point of contact and **must** provide the following information:
 - Name and call back phone number of the State's designated Competent Authority (Organization); and
 - Caller's Name and call back phone number.
3. Request TRIAGE support.
4. DOE/NNSA will:
 - Request a brief description of the incident/event; and
 - Confirm process to submit data via TRIAGE Web or Email
5. Other information TRIAGE will need, if known:
 - Contact person name and phone number, if different from the requestor;
 - Type of Event – Actual/Drill/Test;
 - Type/Model of detector used to collect spectra;
 - Isotopes identified by the detector instrument;
 - Distance between detector and object/package being surveyed;
 - Collection time/duration (300 seconds desired);
 - Description of object/package;
 - Type/Model of Neutron instrument;
 - Neutron Count Rate (per second);
 - Intervening materials between detector and package being surveyed;
 - Brief description of event or occurrence;
 - Photo of the detector and the object/package being surveyed; and
 - If multiple spectra files are being sent, specify which one is of interest, i.e.:
 - data from unknown object/package.
 - data from known radiation source (example: Cesium -137).
 - data from clean background.

Data analysis and material identification information will be provided to the requestor upon completion of the TRIAGE process.

Radiation Backpack Operator Checklist Instructions

Perform operational checks at beginning and end of shift to ensure system is operating properly
 Record date, time and operator name
 Press external button for 1 sec to check system **System Status Check, System ok**
 Record background count rates of gamma and neutron detectors
 Place a 10 µCi (370 kBq) Cs-137 source on unit; verify Golf 5 or higher
 Place a 10 µCi (370 kBq) Cf-252 source on unit; verify November 5 or higher
 Report problems immediately to Team Leader

Radiation Backpack Operator Checklist										
Complete at beginning and end of each shift to ensure system operating properly										
Place a 10 µCi Cs-137 on backpack for 10 seconds - alarm level Golf 5 or higher										
Place a 10 µCi Cf-252 on backpack for 10 seconds - alarm level November 5 or higher										
Shift	Date	Time	Operator	System Status ok	G Bkg (cps)	N Bkg (cps)	G Alarm level	Source	N Alarm level	Source
Example	7/10/10	0900	Smith	✓	750	2	5	Cs-137	5	Cf-252
Begin										
End										
Begin										
End										
Begin										
End										
Begin										
End										
Begin										
End										
Begin										
End										
Begin										
End										
Begin										
End										

Radiation Backpack Operator Checklist

References

Radiation Units and Conversions			
Units	Description	SI Units	Conversion Factor
REM or rem	Dose equivalent	Seivert (Sv)	100 rem = 1 Sv
RAD or rad	Absorbed dose	Gray (Gy)	100 rad = 1 Gy
Curies (Ci)	Activity	Becquerel (Bq)	1 Ci = 3.7 x 10 ¹⁰ Bq

SI and US Units and Conversions					
Activity		Dose Equivalent		Absorbed Dose	
1 TBq	27 Ci	1 Sv	100 R	1 kGy	100 kR
1 GBq	27 mCi	1 mSv	100 mR	1 Gy	100 R
1 MBq	27 µCi	1 mSv	0.1 R	1 mGy	100 mR
1 kBq	27 nCi	1 µSv	100 µR	1 µGy	100 µR
1 Bq	27 pCi	1 µSv	0.1 mR		
1 Bq	1 dps	1 nSv	0.1 µR	1 kR	10 Gy
1 Bq	60 dpm			1 R	10 mGy
		Dose Rate		1 mR	10 µGy
1 kCi	37 TBq	1 Sv/h	100 R/h	1 µR	10 nGy
1 Ci	37 GBq	1 mSv/h	100 mR/h		
1 mCi	37 MBq	1 mSv/h	0.1 R/h		
1 uCi	37 kBq	1 µSv/h	100 µR/h		
1 nCi	37 Bq	1 µSv/h	0.1 mR/h		
1 nCi	2220 dpm				
1 pCi	0.037 Bq				
1 pCi	2.22 dpm				

Natural Occurring (Background) Radioisotopes			
Radioisotope	Symbol	Half-life	Gamma Energy (keV)
Uranium Series	U-238	4.5 x 10 ⁹ years	
Radium-226	Ra-226	1600 years	186
Lead-214	Pb-214	27 min	242, 295, 351
Bismuth-214	Bi-214	20 min	609, 1120, 1238, 1764
Thorium Series	Th-232	1.4 x 10 ¹⁰ years	
Actinium-228	Ac-228	6.1 hours	911, 965
Lead-212	Pb-212	10.6 hours	239
Thalium-208	Tl-208	2.1 min	583, 2614
Bismuth-212	Bi-212	60.6 min	727
Potassium Series			
Potassium-40	K-40	1.3 x 10 ⁹ years	1460
Common Medical Radioisotopes			
Radioisotope	Symbol	Half-life	Gamma Energy (keV)
Technicium-99m	Tc-99m	6 hours	141
Thalium-201	Tl-201	73.1 hours	70, 80, 167
Iodine-131	I-131	8 days	284, 364
Galium-67	Ga-67	78.2 hours	185, 300
Indium-111	In-111	67.4 hours	171, 245
Xenon-133	Xe-133	5.2 days	81
Common Industrial Radioisotopes			
Radioisotope	Symbol	Half-life	Gamma Energy (keV)
Cesium-137	Cs-137	30 years	32, 661
Cobalt-60	Co-60	5 years	1173, 1332
Iridium-192	Ir-192	74 days	295, 308, 316, 468
Americium-241	Am-241	432 years	60
Uranium-238	U-238	4.5 x 10 ⁹ years	766, 1001
Radium-226	Ra-226	1600 years	186, 609, 1120, 1764
Special Nuclear Materials			
Radioisotope	Symbol	Half-life	Gamma Energy (keV)
Uranium-235	U-235	7.1 x 10 ⁸ years	185
Plutonium-239	Pu-239	24,000 years	129, 203, 375, 414
Common Neutron Radioisotopes			
Radioisotope	Symbol	Half-life	Neutron Energy (MeV)
Californium-252	Cf-252	2.6 years	2
Americium-Beryllium	Am-241/Be	432 years	4

For DOE/NNSA Program Support, contact Steve Buntman at steven.buntman@nnsa.doe.gov

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