Detection & Identification

SPIR-Ace

Radio-Isotope Identification Device (RIID)

Technical Description

MIRION TECHNOLOGIES Health Physics Division

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Ionizing radiation of the sources used is dangerous for the worker whenever the protective measures are not strictly applied.
Although our equipment items are built in compliance with the most severe safety standards, the ionizing radiation source represents a danger when the worker is not qualified or not warned.
ANY HANDLING OF RADIOACTIVE SOURCES SHALL MANDATORILY BE PERFORMED BY QUALIFIED AND AUTHORIZED PERSONNEL. Consequently, all precautions shall be taken to prevent any non-authorized or non-qualified person from using this equipment, endangering others and themselves.
Prior to any handling, those qualified and authorized to use this equipment shall get information on the protective measures set forth by the national standards in force.
Abandon or destruction of equipment containing a radioactive source is FORBIDDEN. If no longer required, the user must inform Mirion Technologies (MGPI) SA who will arrange to take the source back (according to the contract) and establish a certificate stating that the source has been taken back. In the event that the source is lost or stolen, the user must inform the appropriate authorities soon as possible.

Directive 2002/96/EU of the European parliament and of the council of january 2003 on waste electrical and electronic equipment (WEEE).
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Revision Log

Ind.	Date	Verified by	Approved by	Origin and description of revision	Revised pages
A	2015-01	J. SPRUYTTE	J. FELLINGER	Document creation	-
B	2016-03	J. SPRUYTTE	J. FELLINGER	DEVS 24359 Updated SPIR-Ace presentation; Updated principle of operation; Updated specifications.	11, 14-15, 18-21, 24-25, 31-37
C	2016-06	J. SPRUYTTE	J. FELLINGER	DEVS 24542 Correction of Gamma energy range value	34
D	2017-02	J. SPRUYTTE	J. FELLINGER	DEVS 25225 Various corrections	All
E	2017-08	C. FOURCADE	J. SPRUYTTE	DEVS 25690 Removed smartphone version	All
F	2018-09	C.FOURCADE	J. SPRUYTTE	DEVS 26992 Removed remote display overview paragraph Updated technical specifications	19 29-33
G	2019-01	C.FOURCADE	J. SPRUYTTE	DEVS 24386 Aligned with NU4 ind.G Updated technical specifications Updated screenshots	All

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Table of Content

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1 Introduction

SPIR-Ace is a versatile Radio-Isotope Identification Device (**RIID**). It is ultra-fast and accurate, compact, user-friendly, and connected.

SPIR-Ace addresses all applications requiring efficient detection and identification of radiological threats in security applications, including **military applications, civil defense**, **border & customs**. It also provides reliable assessment of nuclear materials for **nuclear power plant**, **safeguards**, **labs, OSI/CTBTO agents,** and more.

The identification performance of SPIR-Ace is beyond RIID standards in all conditions, including heavily shielded isotopes, unbalanced mixes of nuclides, SNMs (Special Nuclear Materials) masked by high background, medical isotopes or natural isotopes. **It identifies nuclides at a dose rate of 0.5 µSv/h (50 µR/h) rates within a few seconds**. In less than two minutes, it is able to identify very low levels down to 0.05 µSv/h (5 µR/h).

Small and light, SPIR-Ace is used for source search and to perform measurements with a single hand. The large, bright, and high definition display provides highly readable screens with ergonomic features such as large trend curves, directional search tool (pointing the direction of the source), and a map view. It is highly readable in any circumstances, **even in sunny conditions**.

The **multi-touch display** allows convenient sweeping between displays, and enables functions to share the results with experts. Spectrum analysis features (with cursors, zoom, centroid calculation) and advanced settings are also available with the expert user profile.

Users wearing **gloves** and PPE can operate SPIR-Ace with two physical buttons. The easy user profile suits most of the user's needs, and do not require to use the touch screen; the expert user profile enables the use of specific features like spectrum allysis and provides access to advanced settings.

SPIR-Ace offers **a working day of battery power** for radiation monitoring/detection in typical use conditions (>5 hours in identification mode or >20 hours in monitoring mode). It is extremely easy to recharge using micro USB (like a smartphone).

Geo-localized, and used as a connected device, it provides sharing features such as **Reachback** capability, emails, SMS, and sending data to Incident Management and Decision Support Systems through different protocols. It can be monitored by the **SpirVIEW mobile** supervision software along with the other SPIR devices, like SPIR-Pack or SPIR-Ident Mobile.

NaI (Tl) or **LaBr3** (Ce) detectors provide spectroscopic capabilities up to 50 µSv/h, and the GM tube provides dose rate measurements up to 100 mSv/h. Versions with neutron detection capability are based on ^{6}LiZnS:Ag scintillator. The gamma spectrometry detector doesn't require any source, thanks to an active energy stabilization which works even during sudden temperature changes or when exposed to contamination or sources.

SPIR-Ace complies with the relevant current international standards (IEC 62327, ANSI N42.34) as well as with IAEA guidance.

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2 Features

- **Versatile use for search, detection and identification operations**
- **Better radiological performance than current RIID standards requirements**
- **Designed for security, nuclear accident, and source usage scenarios**
- **Solves heavily shielded and unbalanced Special Nuclear Material masking scenarios**
- **Simple to use "no button to touch" operation with versatile alarm modes**
- **Self energy-stabilized (no source required), operating under quick temperature variations**
- **Long battery life time**
- **External contamination probe connectivity**
- **Integrated GPS for simplified tracking and mapping**
- **Easy data retrieval**
- **Remote display and control via web browser**
- **Data transmission over the Internet**

- **Versatile use for search, detection and identification operations**

SPIR-Ace is a fast and accurate nuclide identifier. Non-expert users benefit of simplified display, automated identification and Reachback to experts, while expert users would analyze the situation and produce documented measurements with the classical start/stop identification mode.

The long battery life and the detection capability enables background radiation monitoring to detect small increases in radiation level.

- **Better radiological performance than current RIID standards requirements**

The Identpro/SIA algorithm allows identifying the isotopes required by ANSI N42-34, IEC 62327, IAEA NSS1 at lower levels or shorter integration times than the standards. The library exceeds currents standards requirements. Examples are available in the "identification" section of this document.

- **Designed for security, nuclear accident, and source usage scenarios**

Seven libraries are available. Two radionuclide libraries address "source search" in accordance with security related needs (homeland security, illicit trafficking).

"Nuclear accident" libraries include the isotopes likely to compose the contamination due to a nuclear plant accident, including short lived fission products.

"Nuclear power" related libraries include fission or activation products, spent fuel, nuclear accident (early releases and late releases).

CTBTO/OSI library (nuclear explosion detection, inspection, collection of evidence) focuses on noble gas (including Xe-133) and some fission products.

Two fully customizable libraries are available for specific needs.

The built-in GPS and the companion app can be used to establish a reliable mapping of vast contaminated areas.

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- **Solves heavily shielded and unbalanced Special Nuclear Material masking scenarios**

Identpro/SIA solves difficult SNM-hiding scenarios. Unlike template algorithms, Identpro/SIA does not rely on predefined scenarios; it accepts very large spectrum shape alteration such as encountered with sources in their transportation containers inside vehicles or cargo.

Where the current standard are requiring 1 to 1 level for a few number of SNMs masking scenarios by Medical or NORM, Identpro/SIA accepts more realistic 1 to 10 ratios or better, and for an extended number of scenarios. Extensive injection studies and practical tests have been conducted well beyond current standards or against standard improvement projects.

- **Simple to use “no button to touch” operation with versatile alarm modes**

SPIR-Ace can operate in a fully automated way, only catching the operator’s attention when a source is detected, and helping him to locate and evaluate the threat. The beginning and the end of spectrum cumulation can be automated, identification is continuously updated. After a quick training, a user perform more precise measurements at a given distance with the regular start/stop integration, by pressing a button.

Alarms are provided by several means: sound alarm and/or an efficient vibrator, and clear information on the screen. The earphone enables discrete use.

The user may acknowledge the alarm to stop the sound and/or the vibration. The sound alarm has a progressive duty cycle to easily distinguish weak alarms from larger ones. In addition, chirps and flashing LED help to locate the source.

All the data is automatically saved, and no user action is required.

- **Self energy-stabilized (no source required), operating under quick temperature variations**

Active stabilization provides accurate energy stabilization even during quick temperature variations and magnetic fields variation (<1 %). It works even in high contamination environment where even the most robust natural radiation energy stabilization would not operate anymore.

- **Long battery life time**

SPIR-Ace uses a low-power mode for the detection/monitoring (like a phone, which remains in sleep mode most of the time, but is able to receive a text message or a call). This provides a large battery lifetime for a RIID, on par with PRD devices. The battery is also easily rechargeable using a micro-USB cable. An optional vehicle power adapter can also be used to recharge the device.

- **External contamination probe connectivity**

The device connects to an optional Alpha-Beta pancake probe to check if an item or a surface is contaminated. Alpha-Beta counting is displayed and logged with the gamma count/dose rate and neutron count/dose rate.

- **Integrated GPS for simplified tracking and mapping**

The device records the position of the device along with radiological data. A map shows the covered areas with colors related to dose rates. It also place tags where the device alarmed.

The reachback data includes the position of the device.

SpirREPLAY software (optional) conveniently retrieves, centralizes, and displays measurements and radiological maps. It includes spatial interpolation methods to produce comprehensive “heat maps”.

- **Easy data retrieval**

Connect SPIR-Ace to a PC by USB, like a phone or a camera. Log files and events lists (including saved spectra) can be easily transferred without specific software. Spectra are directly available at N42 or .spe file formats, depending on the settings.

SpirREPLAY software (optional) enables seamless data transfer to a computer and stores the data inside a database. It handles fleets of SPIR-Aces and other SPIR devices.

- **Remote display and control via web browser**

SPIR-Ace can be remotely controlled using a web page on any computer/tablet/smartphone, via WiFi. This feature may be especially useful to do some measurements at locations where it is not possible to do the measurements and read the display at the same time.

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- **Data transmission over the Internet**

SPIR-Ace uses emails, FTP (File Transfer Protocol), secured HTTP/SSL, and web services to send data to people, radiation monitoring systems, or incident management systems.

SpirVIEW Mobile (not included) allows live supervision from a computer of a fleet of SPIR-Aces along with other devices from the SPIR family (SPIR-Pack, SPIR-Ident Mobile in vehicles or helicopters…) and stores the data inside a database.

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3 SPIR-Ace Presentation

3.1 Device overview

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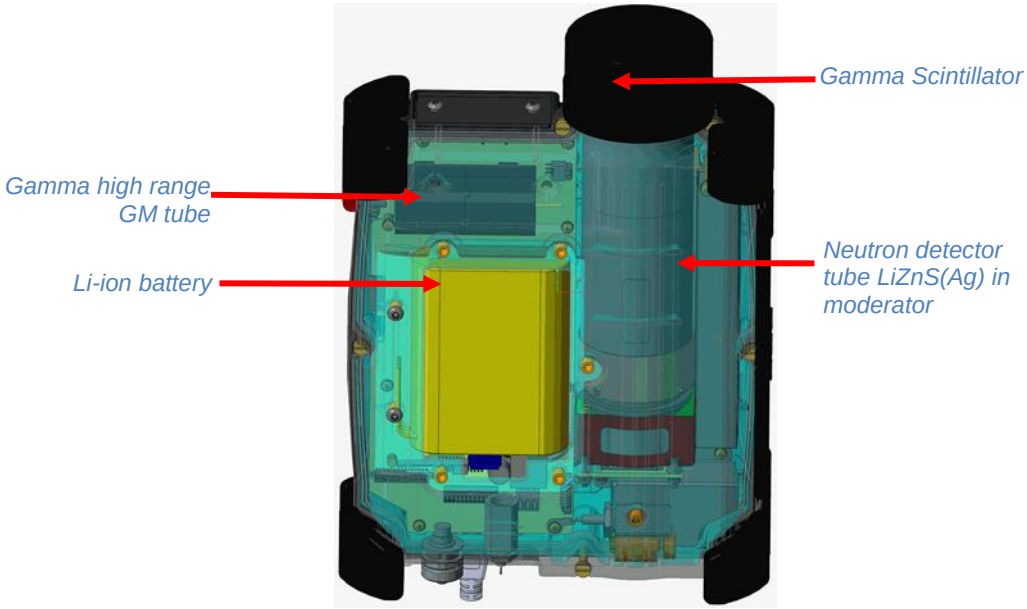
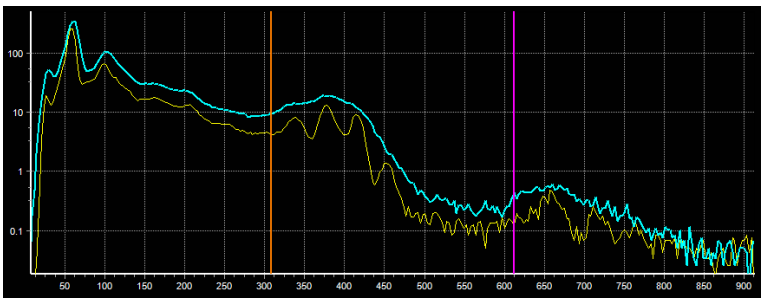
3.2 Detectors



The gamma spectrometric detector may be a NaI(Tl) or a LaBr3(Ce) crystal with a photomultiplier tube. LaBr3(Ce) provides better resolution, enabling more accurate identification in complex mixtures of nuclides, while the NaI(Tl) provides a better sensitivity (due to a larger crystal) enabling a more sensitive source search.



Plutonium spectra with LaBr3 (yellow) and NaI (blue)

The energy-compensated GM (Geiger-Müller) tube is able to provide dose rates from 50 µSv/h / 5 mR/h (or when the gamma spectrometry is saturated). The efficient dead time compensation provides accurate measurements up to 100 mSv/h (10 R/h).

A moderated LiZnS:Ag solid state neutron detector is located along the gamma detector. The detection material is sensitive to thermal neutrons. The internal and external moderators as well as the surrounding environment thermalize fast neutrons making the instrument sensitive to the entire neutron spectrum. The hand or the body also significantly improves the neutron sensitivity.

The neutron level is expressed in count rate. When set, a conversion factor allows calculating neutron dose rate, for a known neutron spectrum, or a source of reference (usually Cf-252, Cm-244, or Am/Be) and a given geometry.

3.3 External probe (optional)

When the external alpha beta “pancake” probe (GMP-25) is connected, the count rate of this probe is monitored and available on the Smart Device application. The red protection cap may be used to discriminate the alphas (stopped by the cap). When set, a beta dose rate can be calculated, based on a supposed nuclide (usually Sr/Y-90) and geometry.

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4 Basic operation

4.1 Starting SPIR-Ace

1

Charge the SPIR-Ace device before use.

2

Press and hold theON/OFF button.
SPIR-Ace initiates a self-test sequence; meanwhile it vibrates, gamma and neutron LED are lit and the splash screen is displayed.

3

After a few seconds, the application is launched.

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4.2 Switching between the various operation modes

1

An operator carries a SPIR-Ace device.
The device is in detection mode, meaning that it is powered on but the interface is off.

2

When the SPIR-Ace detects a source, it vibrates and triggers various visual and sound alarms.
The system behavior depends on the alarm indicators settings.

3

In survey mode, the operator uses the Gauge screen to get a quick evaluation of the detected source.

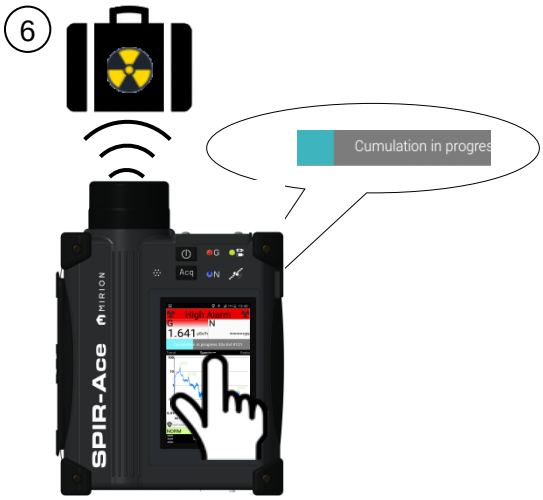
4

Then, the operator uses the Trend screen to see when the source has been detected and at which intensity.

5

Finally, the operator uses the Radar screen to find the source.

6



When the source is found, the operator points it and starts spectrum acquisition. The system switches to identification mode.

7

The analysis result is displayed as an event report. Complete it by adding comments.

When completed, the event report can be shared by email.

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4.3 Operations

There are three ways to operate the SPIR-Ace device:

- **Detection**: The display is OFF, but the device still measures background and trigger alarms in case of anomaly.
- **Search**: The user has the SPIR Ace device in hand to search for a source. The display is ON and the available screens should be adapted to the user's skills (gauge, trend, radar).
- **Identification**: spectrum accumulation.

SPIR Ace behavior is highly customizable, because it is designed to perform various tasks by different user abilities.

4.3.1 User profiles

The Users management function can be found in the system settings. It is used to set various levels of access to the system settings and screens, changing user profile is password protected.

For instance, a system administrator can set an "easy" operator profile with access granted to the gauge screens and to the operational settings, an "expert" operator profile that can access the five main screens and a broader list of settings; and the administrator himself will have access to everything.

4.4 Principle of operation

4.4.1 Identification process

Identification requires high performance spectrometry, providing very accurate measurements thanks to high-speed digital signal processing and active energy stabilization.

The identification requires at least a few seconds of spectrum integration in order to improve the statistics. Depending on the settings, the integration could be "sliding", "start/resume", "periodic". Triggering the identification and therefore the spectra accumulation can be from a user action (ACQ button), or from the device itself.

If triggered by the instrument, the integration continues as long as the condition is met. The ID is then continuously updated and due to higher count number in the spectrum the confidence level of the ID increases.

If user-triggered, automated stop condition such as max counts or max time are available. When the first stop condition is reached, the user can confirm the end of acquisition or resume it. Through-out the acquisition process the ID is continuously updated and the user can see the stability of the decision and the confidence level build up. This is an essential feature to gain confidence in the decision.

To make the source presence very obvious, a "background suppression" function suppresses the IDs of the natural background components (including the Lanthanum peaks for the LaBr3 detector), even in changing background, providing consistency check with a recorded background.

The neutron counts are also integrated, providing lower detection limits.

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4.4.2 Alarm types

Alarms warn the user of a radiation level increase: low alarm and high alarm. The graduation is based on the level of radiation only.

- **Low alarms** are typically for levels that can be due to the background (around 0.05 µSv/h) and those which are certainly not (>0.3 µSv/h for example).
- **High alarms** are alarms corresponding to a threat or a risk of threat, and requires an operator action.

The device also provides a personal safety alarm that can be set in dose-rate, labeled "**Danger**".

In case of saturation of the spectrometry detector, the device automatically switches to a high range detector (GM tube) to measure the high dose rates and protect the spectrometry detector. This change is notified to the user. Low/high alarms may be disabled or acknowledged.

The alarm settings are easily accessible (if allowed by the user profile).

4.4.3 Events

The term "event" is used to designate a continuous series of elementary measurements attached to a same overall measurement and leading to a single memorized result.

When an event occurs, mean and max dose rate, neutron count rate, spectrum and nuclide identifications are saved, along with the GPS coordinates.

Memorized events can be scrolled on the device screen or retrieve for further analysis. Background updates are automatically memorized along the events.

4.4.4 Mapping

The instrument records the GPS position along with the data when available. "Events" summaries including the related spectra are automatically stored in the large memory which avoids user actions and concerns.

SPIR-Ace can display radiological events in real time on a map via the Map screen.

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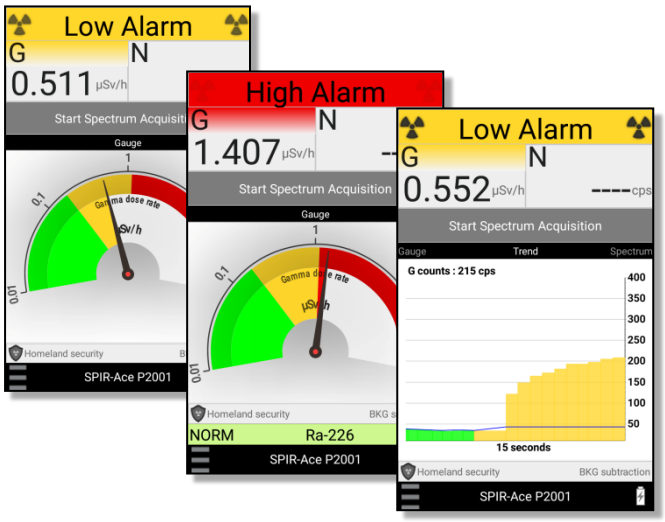
4.5 User interface

4.5.1 Main screens

By swiping finger on the screen, user can easily scroll between 5 mains display screens. Each screen provides level, ID and status information under a different presentation:

- **Large number for easy view of instant values**
- **Instant dose rate gauge**
- **Trend curve: shows count rate variations over last 15 seconds**
- **Spectrum and ID view**
- **Radar source localization helper**
- **Mapping**

4.5.2 Localize and identify a radiation spot



As soon as SPIR-Ace raises an Alarm, Low or High, the user can use the Gauge and Trend Curve for the highest dose rate value location.

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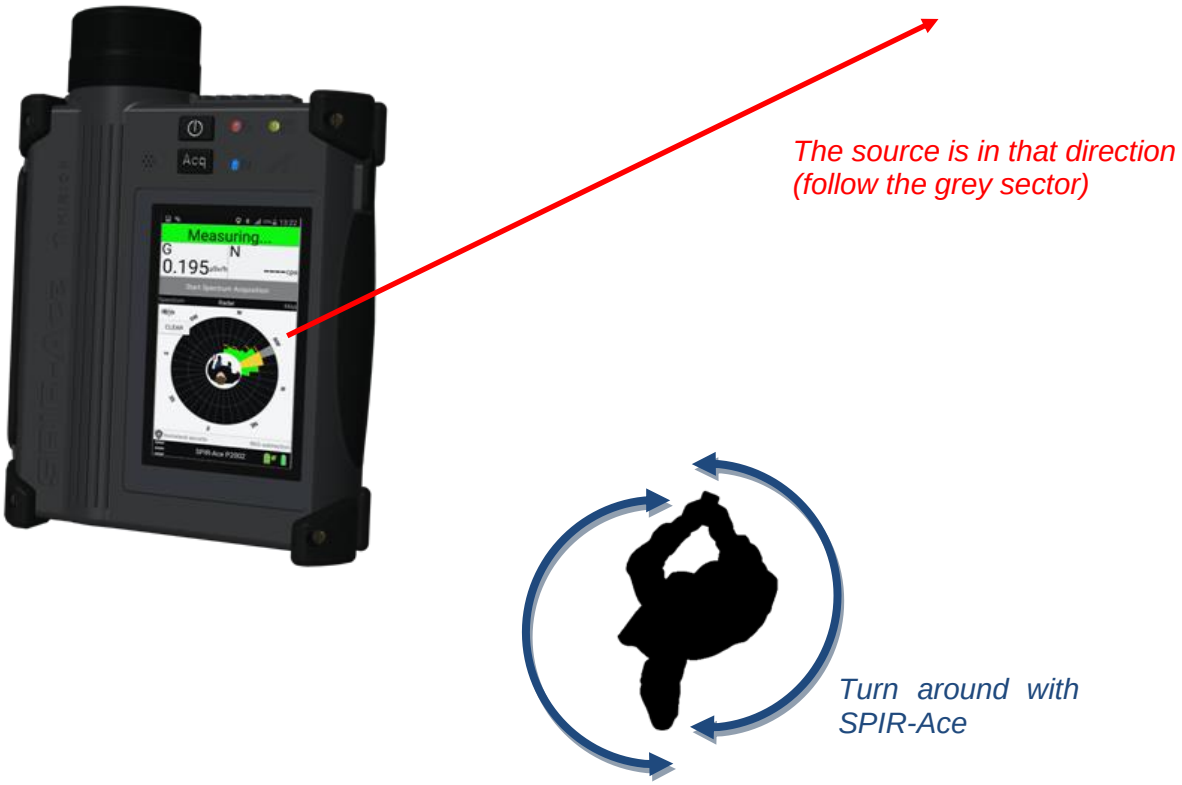
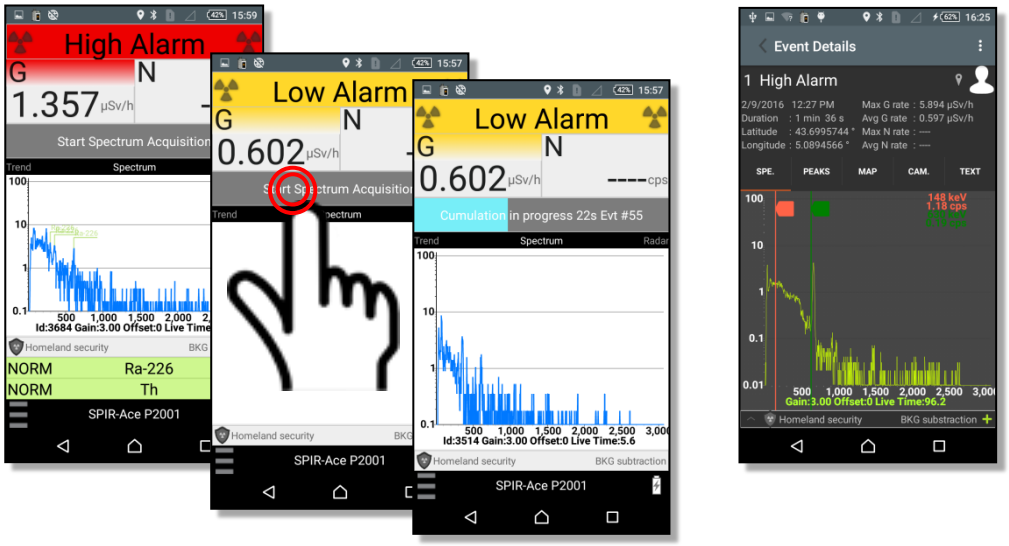
Alternatively, the Radar can be used to observe the direction to the source: Turn right-to-left and left-to-right, and the radar will display the direction of the source, which is the grey sector. Follow that direction, stop, turn again, and follow the new direction.



In case of alarm, the spectrum is automatically accumulated and the Identification is quickly displayed. All acquired spectra are stored as Events with associated measurements.



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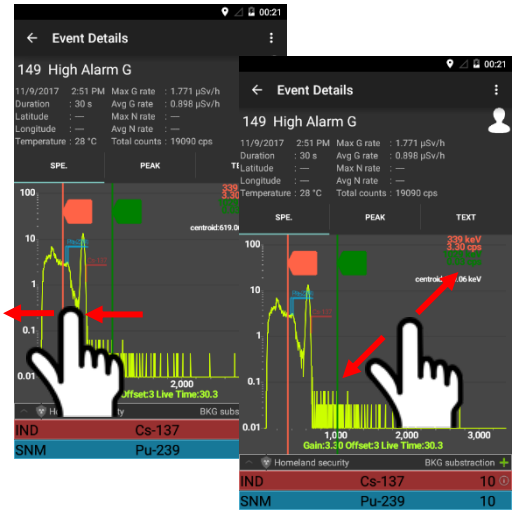
4.5.3 Manage memorized Events

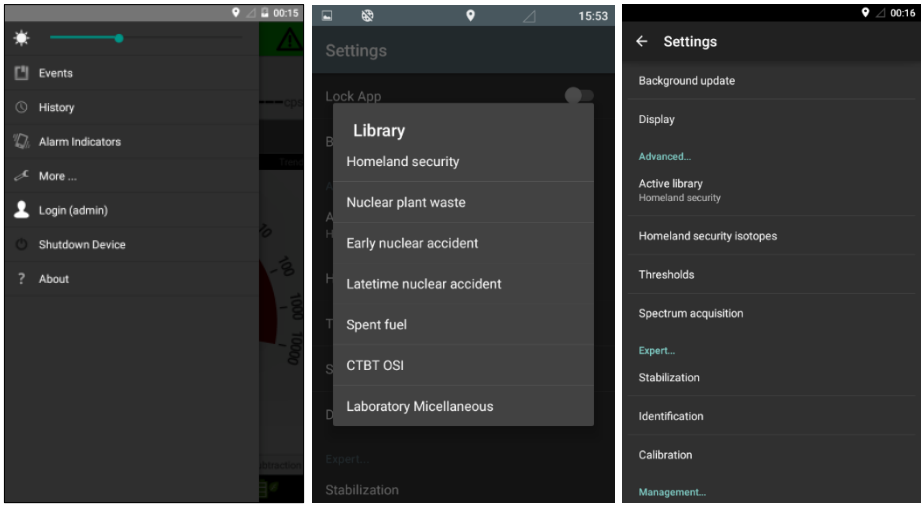


Each memorized Event can be displayed with associated Gamma and Neutron maximum dose rate, count rate, GPS location and Identifications.

Spectra can easily be analyzed by swiping the cursor, zooming with two fingers.

4.5.4 Settings Menu

The first level of settings is available by swiping finger from the left of the screen or by pressing the three-bar button on the bottom-left corner of the screen; user can enable/disable the alarm sound and vibration, update the background level, select the isotopes libraries, view the list of memorized events and access to the second level of settings.



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4.6 Retrieve memorized data

4.6.1 Saving data

The application saves:

- automatically the successive measurements including level, status and real time ID ;
- “events” i.e. manual acquisitions or acquisitions related to detection/alarms according to the settings.

All the data is stored in the micro-SD memory card.

4.6.2 Direct readout of memorized files

4.6.2.1 Measurement log

Successive measurements are stored in the micro-SD memory card.

A .csv text file is created at each SPIR Ace start-up; one line is added at each elementary measurement.

Each line includes day and time, GPS position, device status, gamma dose rate, BKG dose rate, gamma count rate, BKG count rate, neutron count rate, neutron BKG count rate, external probe count rate, status, warnings, event number, integration time, current ID with confidence level (up to 8 identified isotopes).

This file opens under Excel, making data extraction very easy. The event number allows relating an event spectrum to a series of the successive measurements displayed during the spectrum build-up.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	Time	State	Warning 1	Warning 2	Longitude	Latitude	Heading	Speed	LGamma Dose rate (ÂµSv/h)	LGamma BKG dose rate (ÂµSv/h)	LGamma (cps)	LGamma Bkg (cps)	Neutron (cps)	Neutron Bkg (cps)	High range	HGamma filtered (cps)	HGamma filtered Dose rate (ÂµSv/h)
49618	2011-05-03 18:53:20.166	Alarm	ID BKG old		-84.31674	35.92516	20.23	.27	0.078	0.064	540.9	474.3	0.1	0.1	False	0.7	0.221
49619	2011-05-03 18:53:20.850	Alarm	ID BKG old		-84.31674	35.92516	20.23	.27	0.078	0.064	534.5	474.3	0.1	0.1	False	1.7	0.351
49620	2011-05-03 18:53:21.536	Alarm	ID BKG old		-84.31674	35.92516	20.23	.27	0.076	0.064	541	474.3	0	0.1	False	0	0.281
49621	2011-05-03 18:53:22.223	Alarm	ID BKG old		-84.31674	35.92516	20.23	.27	0.075	0.064	532.8	474.3	0	0.1	False	2.9	0.516
49622	2011-05-03 18:53:23.118	Alarm	ID BKG old		-84.31674	35.92516	20.23	.27	0.076	0.064	541.8	474.3	0	0.1	False	0	0.413
49623	2011-05-03 18:53:23.998	Alarm	ID BKG old		-84.31674	35.92516	20.23	.27	0.077	0.064	551.6	474.3	0	0.1	False	0	0.33
49624	2011-05-03 18:53:24.767	Alarm	ID BKG old		-84.31674	35.92516	20.23	.27	0.075	0.064	546.7	474.3	0	0.1	False	0	0.264
49625	2011-05-03 18:53:25.518	Alarm	ID BKG old		-84.31674	35.92516	20.23	.27	0.073	0.064	543.3	474.3	0	0.1	False	1.3	0.343
49626	2011-05-03 18:53:26.274	Alarm	ID BKG old		-84.31674	35.92516	20.23	.27	0.071	0.064	527.6	474.3	0	0.1	False	0	0.274
49627	2011-05-03 18:53:27.029	Alarm	ID BKG old		-84.31674	35.92516	20.23	.27	0.072	0.064	520.3	474.3	0	0.1	False	0	0.219
49628	2011-05-03 18:53:27.784	Alarm	ID BKG old		-84.31674	35.92516	20.23	.27	0.071	0.064	514.4	474.3	0	0.1	False	0	0.175

4.6.2.2 Event data

Events are saved under the format of spectra files whose names are automatically generated using the device number, date and time, and the type of information.

Depending on the settings, spectra file format is .spe format or N42-42 format. Level and ID event information are included in the spectrum comments section when using .spe format.

A new event directory is created every day of use to prevent the directory to become too large.

Example of .spe format

Note that duration, mean, max and background (gamma in µSv/h and Neutron in cps) are included in the header.

Offset is 0, gain is 3keV/ch, the spectrum is linear (no linearity correction factors are needed).

```
$DATE_MEA:
05/03/2011 18:54:01
$MGP_EVT:
346
MANUAL_ACCUMULATION
63.259
$MEAS_TIM:
67.80 67.86
$MGP_AVERAGE:
0.076
0.021
```

Not all data shown

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Example of N42.42 format

The N42 event file format is used for internal backup and for sending files to a FTP server.

File name: SystemName_date_EVT.n42.

Sample of file:

```
<RadInstrumentData xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:MIRION="http://www.mirion.com/downloads/N42SchemaAddin" xmlns="http://physics.nist.gov/N42/2011/N42">
 <RadInstrumentInformation id="RadInstrumentInformation-1">
  <RadInstrumentIdentifier>SPIR-Ace P2007</RadInstrumentIdentifier>
  <RadInstrumentManufacturerName>MGP Instruments</RadInstrumentManufacturerName>
  <RadInstrumentModelName>G-NaI</RadInstrumentModelName>
  <RadInstrumentClassCode>Radionuclide Identifier</RadInstrumentClassCode>
  <RadInstrumentVersion>
   <RadInstrumentComponentName>Software</RadInstrumentComponentName>
   <RadInstrumentComponentVersion>1.0.0.0</RadInstrumentComponentVersion>
  </RadInstrumentVersion>
 </RadInstrumentInformation>
 <RadDetectorInformation id="Gamma">
  <RadDetectorKindCode>NaI</RadDetectorKindCode>
  <RadDetectorLengthValue>7.5</RadDetectorLengthValue>
  <RadDetectorDiameterValue>3.8</RadDetectorDiameterValue>
  <RadDetectorVolumeValue>43.43</RadDetectorVolumeValue>
  <MIRION:Resolution>7.5</MIRION:Resolution>
  <MIRION:Correction>1.61887 -0.17072 0.01313 -0.00023</MIRION:Correction>
 </RadDetectorInformation>
 <RadDetectorInformation id="Neutron">
  <RadDetectorKindCode>LiI</RadDetectorKindCode>
 </RadDetectorInformation>
```

Not all data shown

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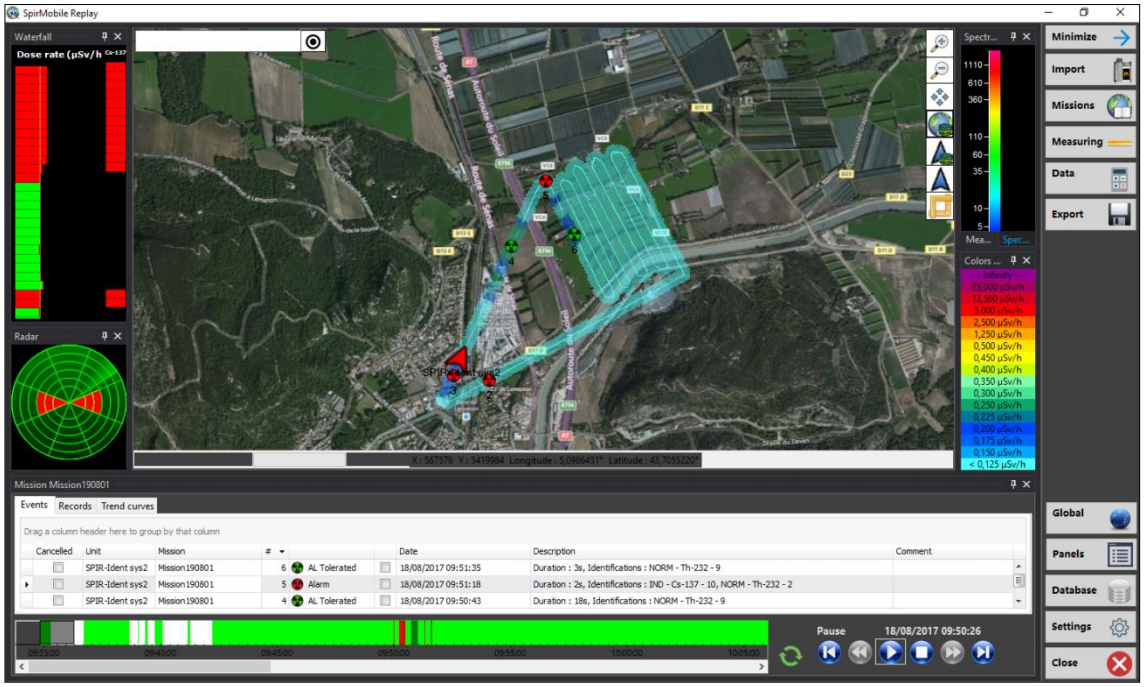
4.6.3 Get the data using SpirREPLAY (Option)

SpirREPLAY is a very convenient tool for event replay, data analysis and storage, providing the following features:

- Seamless data collection from the devices
- Trend curves, timeline, tables of records
- Display event details
- Map display showing the path with colors corresponding to the dose rate (or other measurements), a gridding (extrapolation surrounding the path), and events (click on it to see the details)
- Interpolation map and spatial analysis features (sum of spectra over an area of interest)



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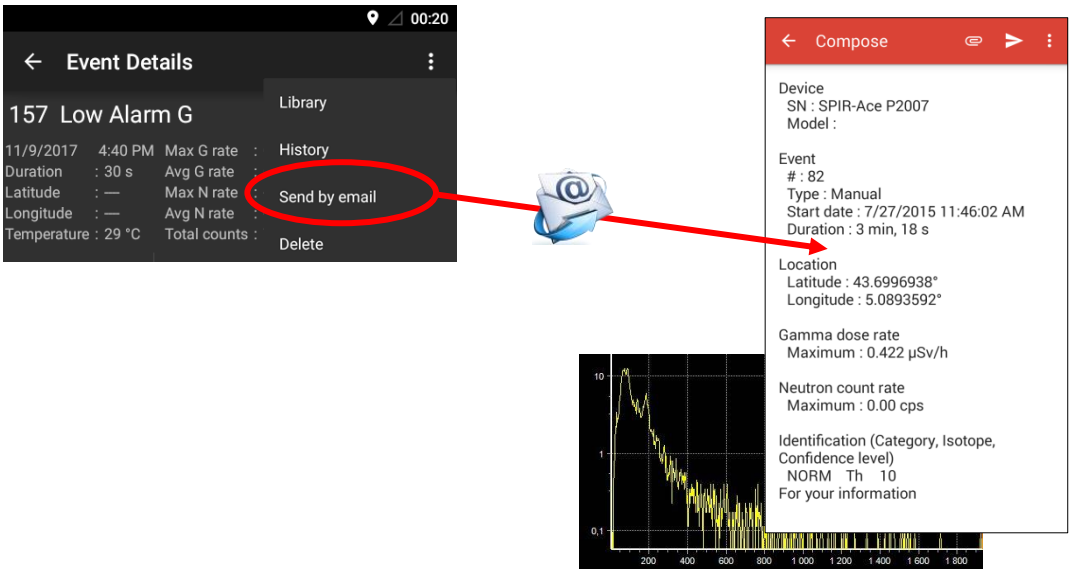
4.7 Reachback functions

The SPIR-Ace device can be connected to the internet and broadcast events by email distribution using WiFi or 3G.

The following is an example of email with spectrum sent by SPIR-Ace:



Note:
Several examples of event data format can be found in §4.6.2.2 Event data.

4.8 Send reports in real time (ANSI N42.42)

The SPIR-Ace device can send reports in real time as N42 files. This feature enables precise, real-time, efficient monitoring of SPIR-Ace status and data. To do so, SPIR-Ace sends files to a FTP server (or web service). The transmission frequency may vary if the system is or is not in alarm.

When the SPIR-Ace device is setup, switched on and connected to a network (via Wi-Fi or 3G), real-time sending of reports is automated.

If the network connection is lost, the event files are stored. They will be sent when the network connection will be restored.

To be able to send reports in real time, the user has to set up the **FTP** (or **Web Service**) and the **Network connection**.

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4.9 Supervise SPIR-Ace with SpirVIEW Mobile

As other devices from the SPIR Family (SPIR-Ident Mobile, SPIR-Pack), SPIR-Ace can be monitored in SpirVIEW Mobile. This enables real time follow-up of the SPIR-Ace instruments: position, status, measurements. This may include mapping: color-coded trajectory with alarm tags.

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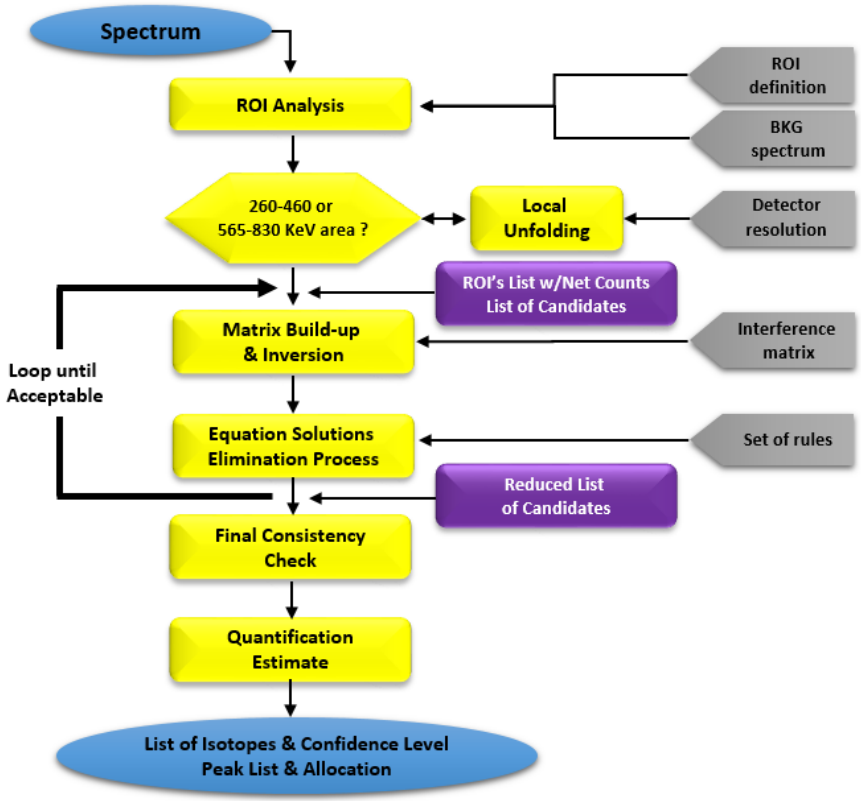
5 Identification

5.1 Identpro/SIA algorithm

The Identpro/SIA identification algorithm is designed and optimized for identification with poor statistics, and for detectors with poor or medium resolution (NaI, LaBr3, CZT). The algorithm first determines intensities by region of interest (ROI). Currently more than 70 ROI's are used ranging from 20 to 2614 keV center energy. If a net intensity is found in the complex 260-460 keV and 565-830 keV regions, the peak intensities are refined by a fitting process. After all the ROI intensities are determined, the algorithm relates these intensities to the isotopes using interference coefficients that have been stored in spreadsheet file.



Flow chart of Identpro/SIA

The next step is to solve the resulting set of linear equations by the method of least-squares, followed by rejecting isotopes yielding unacceptable results and starting a new loop with the reduced number of candidates. Finally the remaining isotopes are screened using additional criteria and decision logic tests

This method does not use a peak search technique and therefore is well adapted for low counts spectra with having large statistical fluctuations. While laboratory measurements typically yield spectra in the 100 000 counts range, Identpro/SIA is able to process spectra with a few 100 counts in the presence of 1000 counts of background. The method does not need an efficient calibration, only volume and detector resolution is required, which makes the method very robust to shielding.

Uncertainty propagation calculation is used to calculate a confidence index on a scale from 1 to 10. Note that unlike some algorithms the response is not a list of choice of responses with some probability among which the user may guess. When several isotopes are listed in the response, it means that the spectrum has been analyzed as being a mixture of these isotopes.

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5.2 Tables of isotopes

5.2.1 List of nuclides by library

HLS (Homeland Security)		Nuclear plant operation & waste	Nuclear accident releases early	Nuclear accident releases late	Spent fuel	CTBTO/ OSI	Laboratory/Various	
Am-Li F-18 Na-22 K-40 Cr-51 Mn-54 Co-57 Co-60 Ga-67 Se-75 Sr-90 (Brem) Mo-99 Tc-99m Pd-103 In-111 I-123 I-125 I-131 Xe-133 Ba-133 Cs-137 La-138 Eu-152	Eu-154 Sm-153 Ho-166m Lu-177 Ir-192 Tl-201 Bi-207 Ra-226 U-232 Th-232 U-233 U-235 U-238 Np-237 Pu-238 Pu-239 Pu-240 Pu-241 Am-241 Cm-243 Cm-244 H(n,g)	K-40 Mn-54 Co-57 Co-58 Fe-59 Co-60 Zn-65 Zr-95 Nb-95 Ru/Rh-106 Ag-110m Sb-124 I-131 Cs-134 Cs-137 La-140 Ce/Pr-144 Ra-226 Th-232	K-40 Co-60 Kr-85m Kr-87 Kr-88 Zr-95 Nb-95 Tc-99m Ru-103 I-131 Te/I-132 I-133 Xe-133 Cs-134 I-135 Xe-135 Cs-137 Ba/La-140 Ra-226 Th-232	Kr-85 (511) K-40 Zr-95 Nb-95 Ru-103 Ru/Rh-106 I-131 Cs-134 Cs-136 Cs-137 Ba/La-140 Ce-141 Ce/Pr-144 Ra-226 Th-232	K-40 Ru/Rh-106 Ag-110m Sb-125 Cs-134 Cs-137 Ce/Pr-144 Eu-154 Ra-226 U-232/Th-228 Th-232 U-235 U-238 Pu-239 Pu-241 Am-241	Kr-85 (511) K-40 Zr-95 Nb-95 Tc-99m Ru-103 Ru/Rh-106 I-131 Te/I-132 I-133 Xe-133 Cs-137 Ba/La-140 Ce-141 Ce/Pr-144 Ra-226 Th-232	F-18 Na-22 Na-24 K-40 Ar-41 Cr-51 Mn-54 Co-57 Co-58 Fe-59 Co-60 Zn-65 Y-88 Sr-90 (Brem) Ru/Rh-106 Cd-109 Ag-110m Sb-122 Sb-124 Ba-133 Cs-137	Eu-152 Eu-154 Ho-166m Yb-169 Tm-170 Lu-176 Ir-192 Bi-207 Po-210 Ra-226 U-232 Th-232 U-235 U-238 Pu-238 Pu-239 Pu-241 Am-241 Cm-243 H(n,g)

SPIR-Ace provides the uranium enrichment and the plutonium burn-up grade. When the acquired spectrum allows this, the messages become:

- U, LEU (lowly enriched), HEU (highly enriched), DU (depleted)
- Pu, LB-Pu (low burnup Pu), HB-Pu (high burnup Pu), MB-Pu (medium burnup Pu)

The uranium and plutonium identification results may be simplified to U and Pu.

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5.3 Identification performances

5.3.1 Identification versus level and integration time

Standard requirements (ANSI N42-34, IEC 62327) for single isotopes require identifying within a minute a source creating a field of 500 nSv/h. **SPIR-Ace will do it in less than 5 seconds**.

In one minute, most of the nuclides are identified at a level of **50 nSv/h**.

Identification time is similar on NaI and LaBr. The better resolution of LaBr compensates for a lower sensitivity and benefits for certain mixed cases.

NaI 0.05 µSv/h	1500s	300s	75s	30s
137 Cs				
60 Co				
241 Am				
57 Co				
75 Se				
192 Ir				
67 Ga				
99m Tc				
131 I				
201 Tl				
DU				
HEU				
Pu 61				
Pu 93				
U 19,9%				
U 3,1%				
U nat				
226 Ra				
232 Th				
40 K				

LaBr3 0.05 µSv/h	700s	140s	35s	15s
137 Cs				
60 Co				
241 Am				
57 Co				
75 Se				
192 Ir				
67 Ga				
99m Tc				
131 I				
201 Tl				
DU				
HEU				
Pu 61				
Pu 93				
U 19,9%				
U 3,1%				
U nat				
226 Ra				
232 Th				
40 K				

Dark green: acceptable decision >95%
Light green: acceptable decision, acceptable decision + unknown >95%
Yellow: acceptable decision, acceptable decision + unknown >50%

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5.3.2 Masking scenarios

Masking scenarios are cases for which a non-threatening isotope such as a NORM or a medical can "hide" a threatening isotope inadvertently or on purpose.

The most well-known masking case is Tc-99m and HEU due to the proximity of the 186 keV peak of U-235 and the 141 keV Tc-99m peak. With high levels of Tc-99m, even using sophisticated pile up rejection, the leftover pulse pile-up tends to mask HEU in very unbalanced scenarios.

A very difficult combination is certainly I-131 and Pu especially when the intensities are largely unbalanced.

Other cases are less known, but also very difficult. E.g. Tl-201 has a secondary peak at 167 keV that can mask the 186 keV peak of U-235. Ga-67 has a 93 keV peak and a 185 keV matching the X ray region and the 186 keV peak of U-235.

Current standard requirements for masking scenarios are weak, covering a limited number of cases and for equal intensity. We studied and optimized the algorithm for all 16 scenarios involving mixtures of the most popular medicals (Tc-99m, I-131, Tl-201, Ga-67) and SNMs (DU, HEU, RGPu, WGPu) in ratios of 1:10. We also optimized the response to masking scenarios involving industrial sources.

NaI 7.5% BKG compensated 60s, G variation = 0, CI>=5 1 to 10 ratio			I-131		Tl-201		Ga-67		Tc-99m	
			I-131	100	Tl-201	100	Ga-67 Pu-239 Ga-67	97 3	Tc-99m	100
DU	U-235 U-235 Unkwn	99 1	I-131 U-235	100	U-235 Tl-201	100	U-235 Ga-67 U-235 Ga-67 La-138	99 1	U-235 Tc-99m	100
HEU	U-235	100	I-131 U-235	100	U-235 Tl-201	100	U-235 Ga-67 U-235 Unkwn Ga-67 Ga-67 U-235 Ga-67 La-138	79 1 19 1	U-235 Tc-99m	100
Pu61	Pu-239 Am-241 Pu-239 Unkwn Am241	96 4	I-131 Pu-239 I-131	99 1	Pu-239 Tl-201	100	Pu-239 Ga-67 Ga-67 Pu-239 Unkwn Ga-67 Unkwn	92 5 1 2	Pu-239 Tc-99m U-235 Pu-239 Tc99m	99 1
Pu93	Pu-239 Pu-239 Unkwn	95 5	I-131 Pu-239	100	Pu-239 Tl-201	100	Pu-239 Ga-67 Pu-239 Unkwn Ga-67 Pu-239 Ga-67 La-138	79 20 1	Pu-239 Tc-99m	100

LaBr 3.7% BKG compensated 300s, G variation = 0, CI>=5 1 to 10 ratio			I-131		Tl-201		Ga-67		Tc-99m	
			I-131	100	Tl-201 Pu-239 Tl-201	99 1	Ga-67 Ga-67 Pu-239	99 1	Tc-99m	100
DU	U-235 U-235 Pu-239 U-235 Unkwn U-235 Ba-133	92 4 3 1	U-235 I-131 U-235 Pu-239 I-131	93 7	U-235 Tl-201 U-235 Pu-239 Tl-201	98 2	Ga-67 U-235	100	U-235 Tc-99m U-235 Pu-239 Tc99m	98 2
HEU	U-235 Ga-67	97 3	U-235 I-131	100	U-235 Tl-201 U-235 Pu-239 Tl-201	99 1	Ga-67 U-235	100	U-235 Tc-99m Ga-67 Tc-99m	99 1
Pu61	Pu-239 Am-241 Pu-239 Am-241 Np237 Pu-239 Unkwn Am241 Pu-239 Am-241 Cs137	63 29 5 3	Pu-239 I-131	100	Pu-239 Tl-201	100	Ga-67 Pu-239 Ga-67 Pu-239 Unkwn	98 2	Pu-239 Tc-99m	100
Pu93	Pu-239 Pu-239 Unkwn	83 17	Pu-239 I-131	100	Pu-239 Tl-201	100	Ga-67 Pu-239	100	Pu-239 Tc-99m U-235 Pu-239 Tc99m	99 1

Note:

The tables are extrapolated from the performances of a 3" diameter NaI and a 1.5" diameter LaBr. The SPIR-Ace detectors are respectively 1.4" and 1". The levels being significantly higher than the background, to get the same performance the time or dose rate should be increased by factors of 5 and 2.3 respectively.

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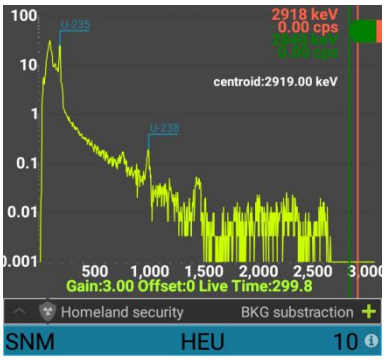
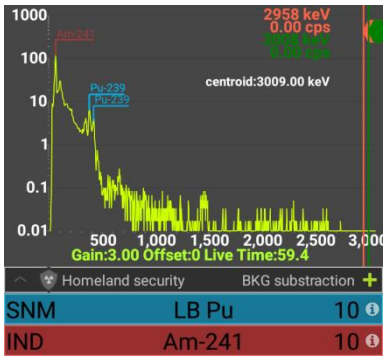
5.4 Examples of identifications

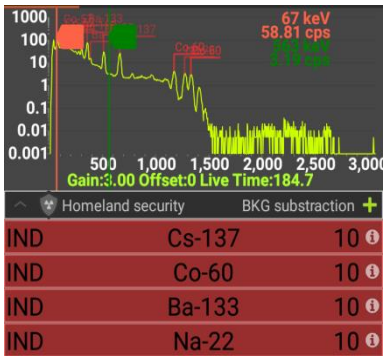
Examples of identification with LaBr3 detector.



HEU

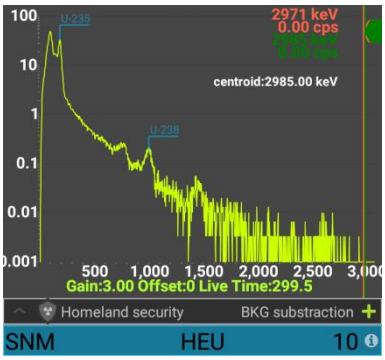


LB Pu
(+ Am-241)

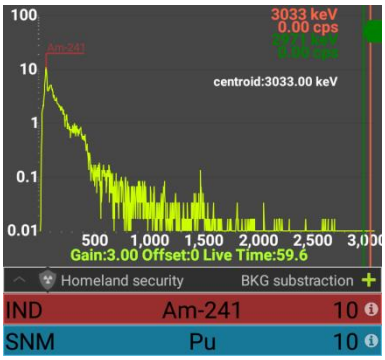


Cs-137
+ Co-60
+ Ba-133
+ Na-22

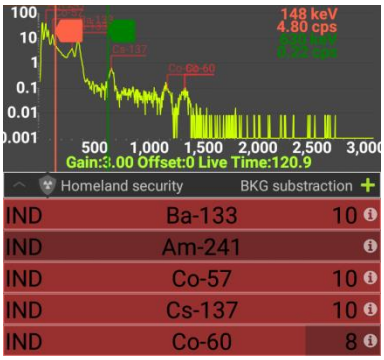
Examples of identification with NaI detector.



HEU



Am-241
+ Pu



Ba-133
+ Am-241
+ Co-57
+ Cs-137
+ Co-60
(50 nSv/h each)

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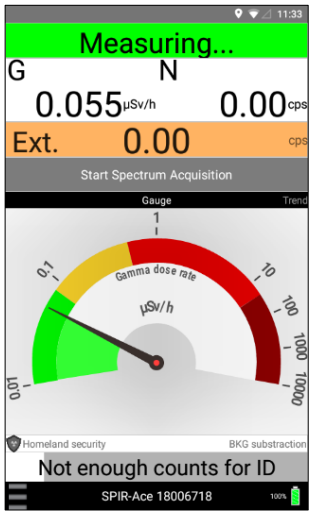
6 Specifications

6.1 Features

6.1.1 Main screens

- **Main display**
  - Gamma dose rate, neutron count rate or external count rate
  - Gamma dose and duration
  - Alarm and acquisition status
  - Identified isotopes (up to 8 simultaneously)
  - Access to the menu (quick settings, event list…)
- **Functional panel**
  - **Gauge screen**: circular gauge for gamma dose rate
  - **Trend screen**: gamma trend curves;
    - In cps with background level indication
  - **Spectrum screen**: Current spectrum view –
    - Y axis Log scale 3 decade or more, auto scale
    - X axis 3 MeV
    - Live time, total counts, total cps
    - Peak allocation in text, all peak or unknown only
  - **Radar screen**: Localization
    - Horizontal 360° radar, persistent display
  - **Map screen**: System tracking and radiological event localization, over a selected map layer.

When connected, the external probe count rate is displayed on all screens, using a dedicated row labeled “Ext.”.



6.1.2 Secondary screens

- **Operational settings**: access to basic functions: events lists, history, alarm indicators, etc.
- **Advanced settings**: access to identification library management, alarm thresholds settings, etc.
- **Expert settings**: advanced functions for experimented users.
- **Management settings**: management of saved data, of users and of password.
- **System calibration**: used for checking and setup of the spectrometric functions.

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6.2 Detection, alarms, spectrometry, identification

- **Detection**
  - SPIR-Ace NaI: 1.4” diam x 2” NaI(Tl) (35 mm diam x 51 mm)
  - SPIR-Ace LaBr3: 1” diam x 1.34” LaBr3(Ce) (25.4 mm diam x 34 mm)
  - Neutron detector (LiZnS crystal): 10 x 10 x 97 mm
  - Gamma high range: GM tube

- **Gamma sensitivity (^{241}Am/ ^{137}Cs/ ^{60}Co)**
  - NaI: typ. 4900 / 800 / 380 (cps) / (µSv/h)
  - LaBr: typ. 3080 / 484 / 300 (cps) / (µSv/h)

- **Neutron sensitivity**
  - Moderated source, 2 cm PEHD: ≥ 0.45 cps/N/s/cm²

- **Energy range**
  - 20 keV to 3 MeV (gamma);
  - 0.025 keV to 15 MeV (neutrons)

- **Energy resolution**
  - SPIR-Ace NaI: =< 7.5% ^{137}Cs (661 keV)
  - SPIR-Ace LaBr3: =< 3.9% ^{137}Cs

- **Dose rate**
  - Displayed dose rate: H*(10)
  - Gamma dose rate range (with NaI or LaBr): 0.01 to 50 µSv/h (1 µR/hr to 5000 µR/hr) (^{137}Cs)
  - Extended range (by GM): 50 to 99 999 µSv/h (5 mR/hr to 9 999 mR/hr)
  - Gamma dose: 1 µSv to 999 999 µSv
  - High-range scintillator cut-off: 1 mSv/h
  - Neutron range: 0 to 1000 cps
  - Gamma/neutron discrimination: no neutron alarm up to 100 µSv/h ^{60}Co

- **Background level follow-up**
  - Dynamic, conditional digital filter

- **Alarms**
  - Low: Detection of a low level of radiation, possibly high background
  - High: Detection of a higher level of radiation
  - Danger: Possibly harmful radiation, step back

- **Alarm thresholds**
  - Gamma level thresholds: Settable in k-sigma over background and/or relative dose rate
  - Gamma danger alarm: Settable in dose rate (absolute)
  - Neutron level threshold: Settable in k-sigma over background

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- **MCA**

Shaping	Digital with pile up rejection
Throughput	>100 000 cps
Spectra characteristics	1024 channels Linearized, stabilized and normalized to 3 keV/ch
Continuous acquisition	Dose rate / count rate / detection : update 0.25 s
Spectra	Update 1 s
Acquisition trigger	On alarm, manual, repetitive
Stabilization	Active, sigma <1%
Identification	Single, bare or shielded, and mixed isotopes identification capability exceeds ANSI N42.34, IEC62327, IAEA recommendations.
Max mixed isotopes	up to 8 mixed (in addition of BKG isotopes if BKG in suppressed mode)
BKG suppression	unlist BKG isotopes if homogeneous to BKG capture spectrum
Masking scenarios	Identifies SNM and main industrials masked by mains medicals for ratios of 1:10 or better

- **Memory (based on 4 GB memory)**

Type	SD card
Format	.spe files, .n42 files
Event / Spectra #	> 50 000 (max 1000 /day)
Memory occupation	3.2 MB / hour (0.25 s rate) + 0.008 MB / event
Memory occupation per 24 h	77 MB / day of 24 hours, including 10 events
Based on 4 GB free memory	51 days with 10 events / day

6.3 Display, controls and interface

Display	Color, transflective TFT, 4.3”, 1440 x 800, projected-capacitative, sun readable touchscreen
LEDs	Power and charge, Gamma pulse, Neutron/External pulse
Sound	Buzzer for alarm and chirp Easy enable/disable; Acknowledgeable
Sound level	81 dB at 30 cm, sine wave @3 KHz (ANSI compliant) ~72 dB at 1 m, sine wave @3 KHz
Vibrator	High intensity, pulsed
Keyboard	Two buttons
Connectors	Connectors protected by caps, waterproof even without cap. Micro-USB for device and power Ancillary contamination probe (waterproof) Earphone (3.5 mm Jack, waterproof cap)
Data export	Events including spectra, .n42 or .spe format Measuring log including day and time, position, levels, alarms, status, IDs

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6.4 Connectivity

■ GPS	GNSS (Global coverage), GPS (L1), QZSS, Glonass (L1), Galileo (E1), AGPS support
■ Cellular	Global data coverage Bands: B5, B8, B2, B1, B4. Frequencies 800/850, 900 AWS1700, 1900, 2100 Uses a nano-SIM card
■ Wifi	IEEE802.11 b/g/n 1x1 2.4 GHz Radio

6.5 Environmental, electrical, physical characteristics

6.5.1 Environmental characteristics

■ **Climatic**

□ Operating temperature	-20°C to 55°C (-4°F to 131°F)
□ Storage temperature	-20°C to 60°C (-4°F to 140°F), without battery
□ Thermal shocks	ANSI N42.34
□ Humidity	Up to 93% RH at 40°C
□ Water and dust ingress	IP65

Note *In case of long-term storage, the battery has to be stored separately, in a controlled environment.*

■ **Shock, vibration and drop**	According ANSI N42.38 & IEC requirements
□ Shocks	10g, 50g, 18ms, ½ sine, IEC 60068-2-27 En
□ Vibration	1g, 10-500Hz, IEC 60068-2-27 Fc
□ Drop	1m on concrete
□ Impact	0.2J

■ **EMI**

□ According ANSI & IEC requirements
□ CE mark (susceptibility: 10V/m)

6.5.2 Electrical characteristics

■ **Battery**

□ Li-Ion rechargeable batteries, built-in charger
□ Battery charge indicator

□ Autonomy	11 hours in survey mode, 4.5 hours in identification mode
□ Charge time	5 hours from supplied fast-charge USB power adapter and cable, at 20°C.

■ **USB**

□ USB 2.0 port for data and charging
□ 5V
□ 500 mA (slow charge), 2A (fast charge)

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6.5.3 Physical characteristics

- **Dimensions** 212 x 154 x 63.5 mm (8.3 x 6 x 2.5 in)
- **Weight**
  - SPIR-Ace LaBr3 + LiZNs 1.37 kg (3.02 lb)
  - SPIR-Ace NaI + LiZNs 1.47 kg (3.24 lb)

6.6 Accessories, options

6.6.1 Included accessories

- Carrying case Plastic
- USB cable and AC adapter For PC, micro B -> type A male
- Allen wrench, size 1.5 For accessing SIM and SD card slots
- Hand strap
- Earphone
- User Manual

6.6.2 Optional accessories

- Rugged carrying case Extremely rugged and waterproof (IP67)
- Contamination probe Alpha – Beta pancake GMP25 with “Binder” plug
- USB DC vehicle power adapter Double
- Allen wrench, size 2 For opening battery compartment

6.6.3 Optional software suite

- SpirREPLAY Centralization, visualization and mapping
- SpirVIEW Mobile Real-time monitoring
- SMI Spectrum analysis and identification

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