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# GRACE System

## Gamma Ray Analysis of Chemical Elements

## For the Identification of Chemical Warfare Agents and Toxic Industrial Chemicals/Toxic Industrial Materials (TICS/TIMS).



# GRACE System

## Gamma Ray Analysis of Chemical Elements

ORTEC worked with Idaho National Labs and the U.S. Department of Defense to develop the Gamma Ray Analysis of Chemicals Elements (GRACE) system. This new system is light, portable, easy to set up, and easy to deploy on missions.



GRACE analyzes and provides on-site identification information about the chemical contents inside munitions or other unopened containers without the need to penetrate the container to take a physical sample. It uses PINS technology which is widely deployed by military and intelligence organizations around the world to identify the contents of “suspect” packages.

The system is comprised of a lightweight stand, a Trans-SPEC-X-N High Resolution Gamma-Ray Spectrometer, a neutron emitting Mini-Gen Neutron Generator, and associated electronics; all controlled by a rugged tablet computer.

The military style backpack case assemblies that house the system components are made of carbon fiber and include active cooling for the electronics within. They are covered with water resistant canvas bags to prevent rain infiltration. They utilize quick disconnect clasps, Velcro closures and Velcro flaps for ease of use and installation. The canvas bags can be ordered in coyote brown or multicam camouflage and can be easily changed dependent on mission parameters.

Backpack #1 or the “power backpack” houses the Trans-SPEC-X-N, tablet computer, miscellaneous stand components and power/control electronics (which are accessible via a control panel at the side of the backpack). Remote power is supplied to the system via an internal lithium-ion battery. The battery within the unit is removable/swappable via a door at the base of the case and there is storage space for a spare battery in Backpack #2. Mains power for charging of the internal battery is supplied to the system via a power brick with a military vehicle 24V NATO plug (this connection does not power the system for operation). Weight is ~58.5 lb. Operating temperature is –10 to 40ºC.

Backpack #2 houses the stand body, Mini-Gen neutron generator, control cables, spare battery (if desired) and quick setup documentation. Weight is ~58.5 lb.



Carbon Fiber shell covered with water resistant canvas.







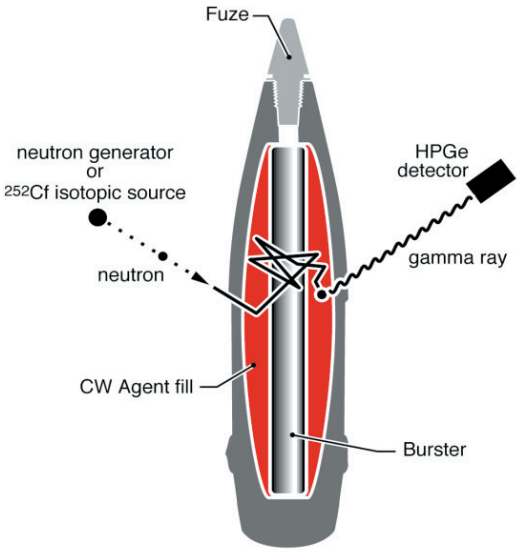
Control Panel of the power backpack.

# GRACE System

## Gamma Ray Analysis of Chemical Elements

### GRACE Overview

The chemical identification software identifies dangerous compounds and mixtures non-destructively. The test object need not be opened or touched, providing significant safety benefits. As shown, the system probes a test object with neutrons that excite the atomic nuclei within, causing the excited nuclei to produce gamma rays. The energy intensity pattern or spectrum of these gamma rays is unique for each chemical element, and by analyzing the gamma-ray spectrum, the software identifies the chemical elements inside the test object and determines if the object contains a chemical warfare agent, TICs/TIMs, a fill (such as sand), or a smoke generating chemical.




### How It Works

The GRACE uses neutrons produced by a neutron generator to excite nuclei inside the object under test. The fusion of deuterium atoms (D + D) inside the neutron generator results in the formation of He-3 ions and a neutron with a kinetic energy of approximately 2.5 MeV. The neutron generator produces ten million neutrons per second. The generator emits neutrons omni-directionally, and approximately 1,000 neutrons per second strike each square centimeter of the test object surface. Since neutrons are a very penetrating form of radiation, most pass through the test object casing and interact with the chemicals inside.

Neutrons from the generator excite the nuclei they encounter by inelastic scattering or by neutron capture. In either case, the excited nuclei decay to their ground states by gamma-ray emission, and the gamma rays are characteristic of the emitting nucleus. That is, the gamma-ray energies and intensities vary, often strongly, from one nucleus to another. For example, the hydrogen nucleus emits a 2.2-MeV gamma ray under neutron bombardment, while a phosphorus nucleus emits a 1.3-MeV gamma ray.

The neutron-induced gamma rays are measured by a new, light-weight, high-purity germanium (HPGe) spectrometer and sorted into a spectrum by the spectrometer electronics. By analyzing the spectrum, the chemical elements excited by the neutrons are determined, and the chemical substance inside the test object can be identified.



### GRACE in Operation

Developed for ease of field deployment, GRACE is both man-portable and rugged. Its components include a mechanically cooled spectrometer with integrated multichannel analyzer, a neutron generator, a stand and shielding for the detector, and a rugged tablet computer for user interface.

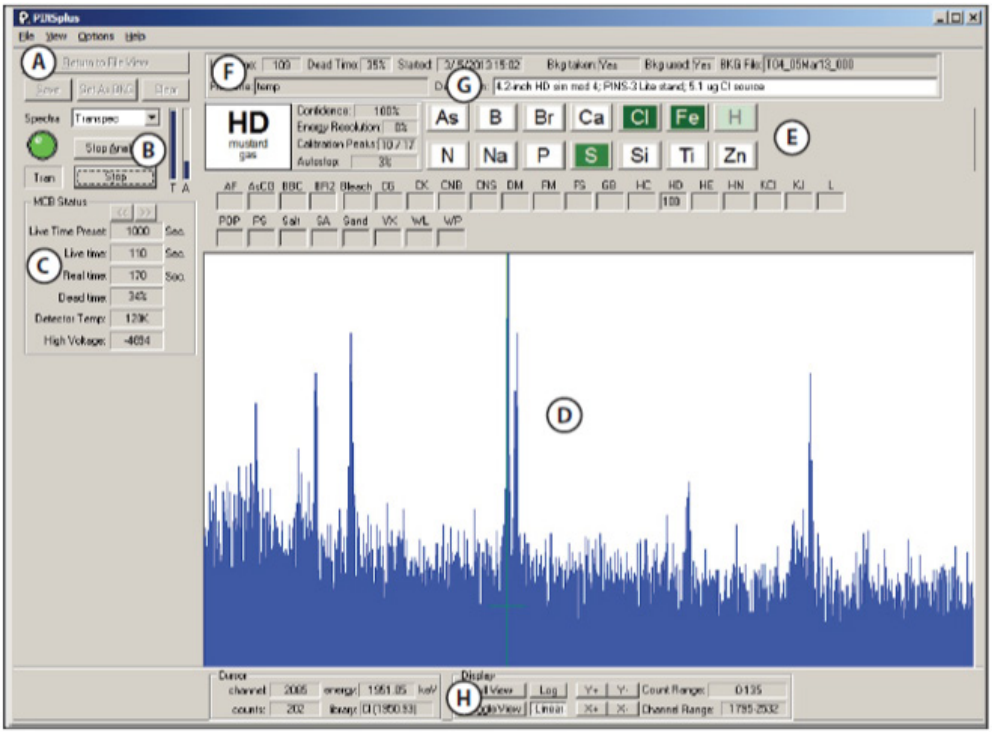
Customized software displays the data in real time as it is gathered and offers powerful options for monitoring and analysis.
The tablet computer serves as the system control panel. The computer allows the user to initialize the instrument, start and stop data acquisition by the gamma-ray spectrometer, and display and analyze the resulting gamma-ray spectra.



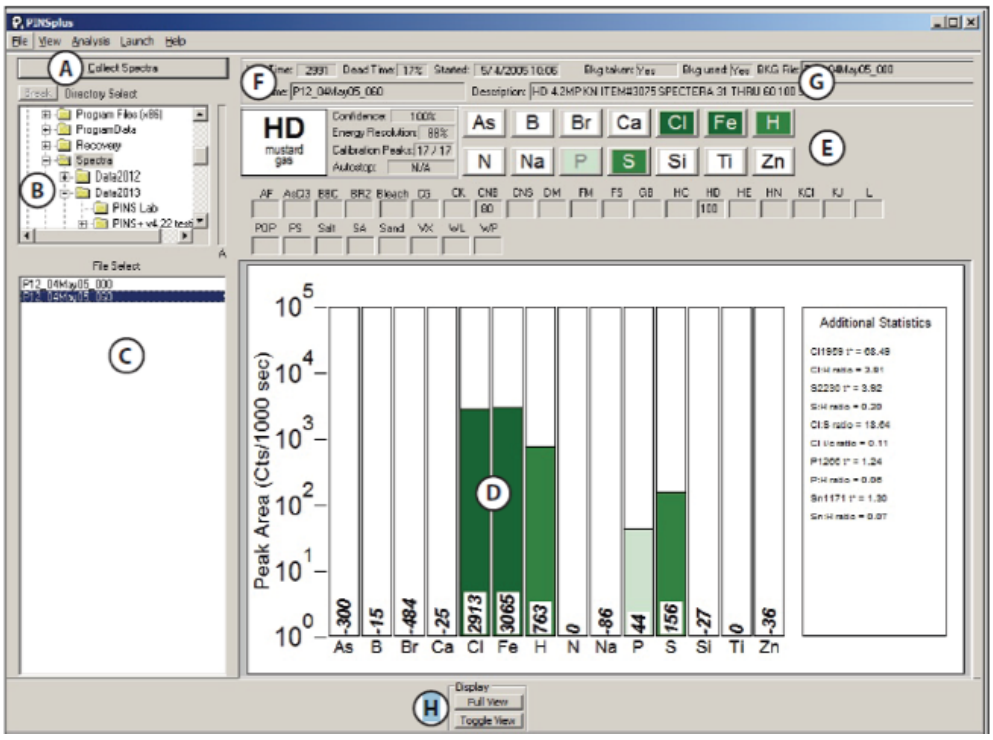



# GRACE System

## Gamma Ray Analysis of Chemical Elements




A) Return to file View Button
B) Analysis Box
C) MCA Status Box
D) Spectra Display
E) Element Browse Buttons
F) Analysis Information Box
G) Assay Information Box
H) Toggle View Button




A) Collect Spectra Button
B) Folder Browser
C) Results Display
D) Element Browse Buttons
E) Analysis Information Box
F) Assay Information Box
G) Toggle View Button

# GRACE System
## Gamma Ray Analysis of Chemical Elements

### Trans-SPEC-X-N Mechanically Cooled High Purity Germanium Spectrometer

Unlike the liquid-nitrogen-cooled HPGe spectrometers used in previous systems, GRACE uses the Trans-SPEC-X-N mechanically cooled HPGe spectrometer, requiring no liquid nitrogen. The electrical power required to cool the spectrometer detector is approximately 30 watts. The Trans-SPEC-X-N lithium-ion battery can keep the detector cold for 6 hours. The Trans-SPEC-X-N provides a flexible and modular solution to support field inspections of chemical threats with the following additional features:




- No Liquid Nitrogen — Miniature, high-reliability, "run-forever" Stirling-cycle cooler eliminates the need for $LN_2$; detector element is encapsulated in high reliability, low loss, all-metal sealed cryostat.
- High Sensitivity — Large (>50% relative efficiency) HPGe detector.
- High Stability — Digital electronics give you the solution for the toughest analysis in the toughest conditions.
- Bright and Clear — VGA resolution display with touch sensitive operator screen.
- All-in-one Integrated Package — Rugged and compact with no interconnections — easy to setup and go. Setup typically <15 minutes for trained users.
- Flexible — A variety of power sources can be used, including internal battery, supplemental external battery, vehicle battery (any 12 VDC), and AC line power; all with automatic switchover.

### Mini-Gen Neutron Generator



The Mini-Gen Neutron Generator is a derivative of the popular P385 neutron generator in a more compact format, with the DNC III control interface. The Mini-Gen is 66% lighter and occupies 60% less space. All input and output signals are consolidated into two connectors on the front face.

The integrated front connectors have inputs for control of advanced functions such as a run timer, data logging, pulse counting, stand-by, and a facility interlock. The connectors have outputs for the source pulse and user adjustable Delay TTL signals.

The new design combines the accelerator head and control electronics into a single, compact unit.

### Power Management System

Supports the Trans-SPEC-X-N, Mini-Gen and tablet computer.

DC/DC Power Supply keeps the system batteries fully charged while connected to vehicle power.
- 24 VDC to 16 VDC, 300 W
- 24 V NATO plug for military vehicle.

AC/DC Power Supply supplies power to the system via a wall outlet while in storage.
- 110/240 VAC to 16 VDC, 300 W

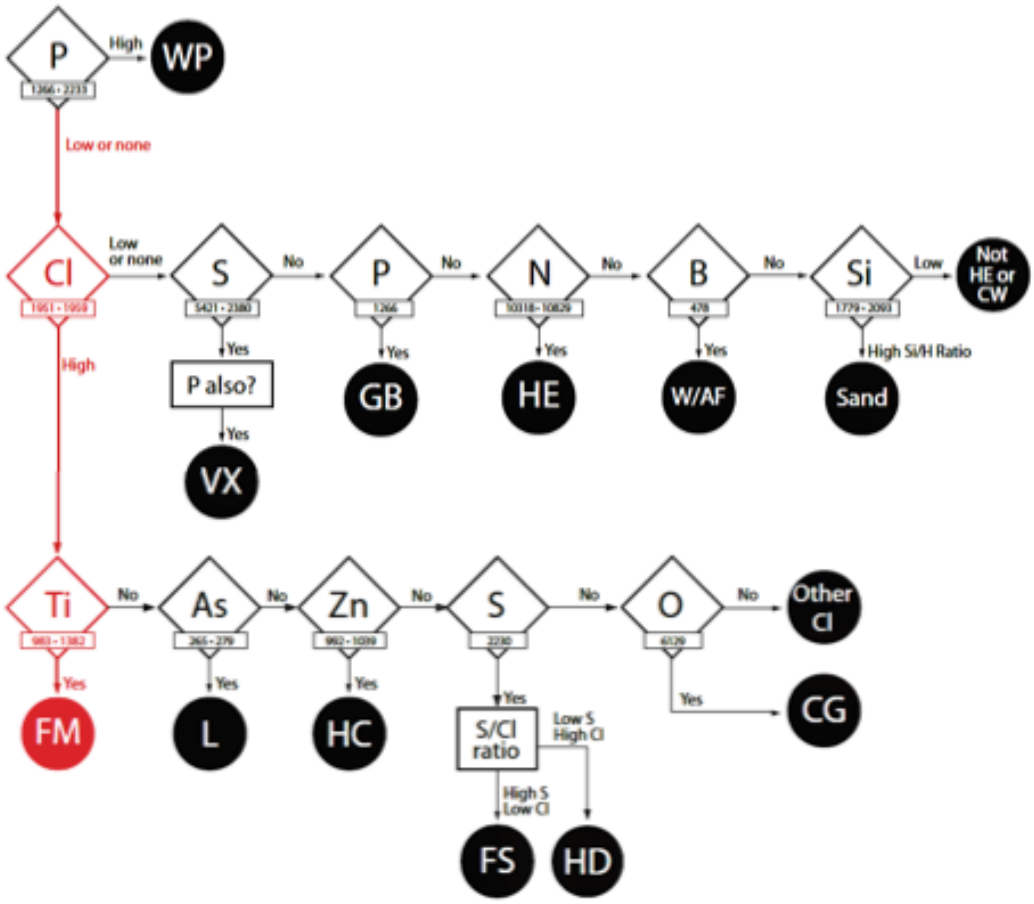
Battery Power
- System will operate on battery power when removed from vehicle power.

# GRACE System
## Gamma Ray Analysis of Chemical Elements

### Auto Analysis of Chemicals

The GRACE data acquisition program records and displays the incoming spectra measurements from the Trans-SPEC-X-N. It also analyzes the spectrum being recorded every 10 seconds, fitting the peaks of interest, re-calibrating the energy scale, and performing a chemical analysis. The chemical analysis method, based on the shown decision tree logic, attempts to identify the chemical inside the object under test. The probabilistic method traces through every path in the decision tree, and it computes a score for each possible content chemical. The chemical with the highest score is chosen as the content chemical.

The chemical analysis method is fast and accurate, and it is easy to expand the list of chemicals that GRACE can identify automatically. Currently, the GRACE auto analysis software recognizes the chemicals shown to the right.




**Chemicals Automatically Identified by GRACE**

**Chemical Warfare Agents**
BR-2
CG
CK
GB
HD
HE
HN
VX
WL

**Practice Fills**
Bleach
POP
Sand
Water-antifreeze

**Smoke Chemicals**
FM
FS
HC
WP
L

## Specifications

### Gamma-Ray HPGe Spectrometer

| | |
|---|---|
| **Model** | ORTEC Trans-SPEC-X-N |
| **Relative Efficiency** | >50% typical (ANSI/IEEE 325-1996) |
| **Energy Resolution** | <1600 eV @ 122 keV and ≤2.5 keV @ 1332 keV (FWHM Warranted at optimum settings and detector type) |
| **Multichannel Analyzer (MCA)** | Built in digital signal processing MCA |
| **MCA Channels** | Up to 16k |
| **Dimensions** | 16.7 in. L x 5.6 in. W x 8.3 in. H (42.4 cm L x 14.1 cm W x 21 cm H) |
| **Weight** | 16.5 lb. (7.5 kg) |
| **Input Power** | 12–17 V DC @ 30 Watt |
| **Internal Battery Life** | ~6 hours @ 77°F (25°C) for a cold detector |
| **Initial Cooldown Time** | <10 hours @ 77°F (25°C) |
| **Maintenance** | Periodic detector annealing is recommended as part of a routine maintenance program for any HPGe detector operating in a high neutron environment. The scheduling of this maintenance will be dependent on the utilization and intensity of the high energy neutron source. |

### Tablet Computer

| | |
|---|---|
| **Model** | Panasonic Toughbook CF-20 |
| **Operating System** | Windows 10 Pro |
| **Memory/Storage** | 8 GB RAM / 256 GB SSD |
| **Battery Operation Time** | Up to 8 hours. |
| **Display** | 10.1" sunlight viewable (1920x1200), anti-reflection, anti-glare, glove enabled touchscreen. |
| **Dimensions** | 272 mm x 196 mm x 16.4 mm (10.7 in x 7.72 in x .65 in) |
| **Weight** | 950 grams (2.09 lb) |
| **Ruggedness** | IP65 water and dust resistant |

### Neutron Generator

| | |
|---|---|
| **Model** | Mini-Gen |
| **Neutron Yield, Nominal** | 6E+06 n/s |
| **Pulse Range** | 0.5 to 20 kHz |
| **Duty Cycle** | 5% to 90%, continuous |
| **Mean Neutron Energy** | 2.5 MeV |
| **Control Interface** | RS-232 or Ethernet (UDPv4) |
| **Safety Features** | Key lock, emergency On/Off, automatic pressure interlock switch, flashing warning light |
| **Pressurized Gas Shipping Permit** | DOT SPECIAL PERMIT 14690, allows the unit to ship fully pressurized. A copy of this special permit may be obtained at https://cms7.phmsa.dot.gov/approvals-and-permits/hazmat/file-serve/offer/SP14690.pdf/offerserver/SP14690 |
| **Total Weight** | 16 pounds (7.3 kg) |
| **Power Consumption** | Less than 75 watts typical |
| **Control Module Details** | Open-source text and GUI |
| **Maximum Accelerator Voltage** | 130 kV |
| **Typical Tube Lifetime** | 1500 hours @ 3E+08, 4500 hours @ 1E+08 |
| **Outputs** | Source, Delay-1, Delay-2, Delay-3, Control |
| **Dimensions** | 4.25 x 8 x 10 inches |
| **Operating Range** | 20 to 70 µA, 60 to 130 kV |
| **Input Power** | 24 V DC ±10% |
| **Operating Temperature** | –10 to +50ºC |
| **Minimum Pulse Width** | 5 µs |

# GRACE System

## Gamma Ray Analysis of Chemical Elements

## Ordering Information

| Model | Description |
|---|---|
| **GRACE-CB-L** | GRACE Chemical Element Analysis System. Includes Trans-SPEC-X-N HPGe Gamma Spectrometer, Mini-Gen Neutron Generator, INL Analysis Software, Tablet Computer, Measurement Table Assembly, Portable Power Supply, AC/DC Power Cables, Backpacks with Coyote Brown Cover, Frame (Size L), and Transport Cases. |
| **GRACE-CB-XL** | GRACE Chemical Element Analysis System. Includes Trans-SPEC-X-N HPGe Gamma Spectrometer, Mini-Gen Neutron Generator, INL Analysis Software, Tablet Computer, Measurement Table Assembly, Portable Power Supply, AC/DC Power Cables, Backpacks with Coyote Brown Cover, Frame (Size XL), and Transport Cases. |
| **GRACE-MC-L** | GRACE Chemical Element Analysis System. Includes Trans-SPEC-X-N HPGe Gamma Spectrometer, Mini-Gen Neutron Generator, INL Analysis Software, Tablet Computer, Measurement Table Assembly, Portable Power Supply, AC/DC Power Cables, Backpacks with Multicam Cover, Frame Size (L), and Transport Cases. |
| **GRACE-MC-XL** | GRACE Chemical Element Analysis System. Includes Trans-SPEC-X-N HPGe Gamma Spectrometer, Mini-Gen Neutron Generator, INL Analysis Software, Tablet Computer, Measurement Table Assembly, Portable Power Supply, AC/DC Power Cables, Backpacks with Multicam Cover, Frame Size (XL), and Transport Cases. |
| **Options and Accessories** | |
| **GR-RAD-NUKE-SW** | Addition of Radiological and Nuclear Identification Software. Can only be ordered at time of GRACE System order. |
| **GR-COVER-CB** | Backpack Covers - Coyote Brown |
| **GR-COVER-MC** | Backpack Covers - Multicam |
| **GR-FRAME-CB-L** | Harness Frame - Coyote Brown - Size Large |
| **GR-FRAME-CB-XL** | Harness Frame - Coyote Brown - Size Extra Large |
| **GR-FRAME-MC-L** | Harness Frame - Multicam - Size Large |
| **GR-FRAME-MC-XL** | Harness Frame - Multicam - Size Extra Large |
| **GR-BATTERY** | Backpack Battery - Spare |
| **GR-CHARGER** | Backpack Battery Charger - Spare |
| **GR-PWR-PT-CBL** | Cable for System Operation via AC or DC Mains Power (one included with system) |
| **TRANS-SPEC-X-N** | Trans-SPEC-X-N Portable Spectrometer complete with universal mains supply and MAESTRO Pro software. |
| **SIMULANTS-12** | Calibration and Training Simulants. Qty 1 EA: CG, HE (Comp. B), HE (HMX), PoP, FS, GB, HC, HD, WP, L, VX, and Sand. Includes HazCom labels and 3 shipping drums. |

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Specifications subject to change
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