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Department of Energy

Ohio Field Office
Fernald Closure Project
175 Tri-County Parkway
Springdale, Ohio 45246
(513) 648-3155

SEP 2 2005

Mr. James A. Saric, Remedial Project Manager
United States Environmental Protection Agency
Region V-SRF-5J
77 West Jackson Boulevard
Chicago, Illinois 60604-3590

DOE-0321-05

Mr. Thomas Schneider, Project Manager
Ohio Environmental Protection Agency
Southwest District Office
401 East Fifth Street
Dayton, Ohio 45402-2911

Dear Mr. Saric and Mr. Schneider:

TRANSMITTAL OF SODIUM IODIDE AND HIGH PURITY GERMANIUM SYSTEMS SOFTWARE OPERATIONS MANUAL, SOFTWARE VERSIONS 3.1 AND 3.2

Enclosed for your information is the recently issued Sodium Iodide and High Purity Germanium Systems Software Operations Manual, covering Versions 3.1 and 3.2 of the software used by the Fernald Closure Project Real Time Instrumentation Measurements Program. Prior versions of this manual were issued under the Idaho National Engineering and Environmental Laboratory (INEEL) document system, since INEEL staff performed the programming. The document being transmitted to you reflects several significant software improvements implemented in 2004, including an improved sodium iodide (NaI) gamma ray spectrum analysis technique and a more rigorous treatment of NaI minimum detectable concentrations and measurement uncertainties. The theoretical background for these software changes was described in detail in two documents that were transmitted to you earlier this year: 1) User Guidelines, Measurement Strategies, and Operational Factors for Deployment of In Situ Gamma Spectrometry at the Fernald Site (Users Manual, Revision 1) and 2) Measurement Uncertainties and Minimum Detectable Concentrations for the In Situ Gamma Spectroscopy Systems Used at the Fernald Site.

If you have any questions or require additional information, please contact Johnny Reising at (513) 648-3139.

Sincerely,

Johnny Reising

for William J. Taylor
Director

FCP:Reising

Enclosure

cc w/enclosure:
J. Reising, OH/FCP
G. Jablonowski, USEPA-V, SR-6J
C. Connell, ATSDR
M. Carpenter, INEEL
M. Cullerton, Tetra Tech
L. Roybal, INEEL
M. Shupe, HSI GeoTrans
R. Vandegrift, ODH
AR Coordinator, Fluor Fernald, Inc./MS78

cc w/o enclosure:
K. Alkema, Fluor Fernald, Inc./MS1
J. Chiou, Fluor Fernald, Inc./MS88
F. Johnston, Fluor Fernald, Inc./MS12
C. Murphy, Fluor Fernald, Inc./MS1
ECDC, Fluor Fernald, Inc./MS52-7

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SODIUM IODIDE AND HIGH PURITY GERMANIUM SYSTEMS SOFTWARE OPERATIONS MANUAL SOFTWARE VERSIONS 3.1 AND 3.2

FERNALD CLOSURE PROJECT
FERNALD, OHIO

AUGUST 2005

U.S. DEPARTMENT OF ENERGY
FERNALD AREA OFFICE

20310-RP-0010
REVISION 0

ACKNOWLEDGEMENT

Bechtel BWXT Idaho LLC operates the Idaho National Engineering and Environmental Laboratory (INEEL) for the U.S. Department of Energy (DOE), Office of Environmental Management, under DOE Idaho Operations Office Contract DE-AC07-99ID13727. The work of designing and building the Excavation Monitoring System (EMS) was performed by a Bechtel BWXT team from the INEEL. The work was supported by a DOE technology assistance grant from the Office of Science and Technology (OST). Funds were provided by the Subsurface Contaminants Focus Area under Technical Task Plan OH11SS31, and also by the Decontamination and Decommissioning Focus Area under Technical Task Plan OH11DD31. The purpose of this work was to deploy an Integrated Excavation Control System (IECS) to expand the Fernald Closure Project's (FCP) capabilities for the *in situ* measurement of radionuclides in soils to locations where the site's current *in situ* capabilities cannot be used, namely to deep excavations and trenches. An interdisciplinary team of scientists from Fluor Fernald, Inc. and Argonne National Laboratory worked with the scientists and engineers from INEEL on the project.

Michael V. Carpenter was the INEEL project manager for this work and Lyle G. Roybal was the engineer who wrote the software used to control the EMS data acquisition and analysis. Prior versions of this document were written by Lyle Roybal and published as INEEL documents. Mr. Roybal also wrote a draft of this document, describing Version 3.1 of the NaI and HPGe operating software. However, project funds were expended before the document could be published. Personnel from Fluor Fernald edited Mr. Roybal's draft document to produce this report, which serves as documentation of the capabilities and analysis techniques of Version 3.1 of the real time software. The organization and technical content of this document are Mr. Roybal's. FCP personnel made changes to correct typographical errors and to clarify certain passages. The team from INEEL, and Mr. Roybal in particular, were key elements in the success of this project. It is no exaggeration to state that this document would not have been possible without Mr. Roybal's programming expertise and the draft document upon which this report is based.

ABSTRACT

The Idaho National Engineering and Environmental Laboratory (INEEL) and the FCP have jointly developed a suite of field-deployed analytical systems to rapidly scan and analyze surface soil contamination. Two base systems have been developed to measure and analyze the radioactive components of soil contamination using real-time *in situ* instrumentation. The first system is designed to characterize large land areas quickly and uses a sodium iodide (NaI) spectrometer as the basis for radiological measurements. The second system is designed to provide high-accuracy confirmatory data in suspect contaminated and remediated areas and uses a high purity germanium (HPGe) spectrometer as the basis for measurement. The FCP has six sodium iodide spectrometers that are deployed from any of four different platforms depending on the scope of the survey at hand. These platforms include the large tractor-based unit [the Radiation Tracking System (RTRAK)] used to survey large, relatively flat areas, the excavation monitoring system which is deployed from a back-hoe and used to survey pits and trenches, the Gator used in large areas where the terrain is difficult, and the hand-pushed Radiation Scanning System units which are modified strollers used to survey smaller areas where access by motorized vehicles may be limited. Currently, there are seven HPGe systems used on the FCP site. These are used primarily in a stationary mode.

The mobile sodium iodide concept was initially developed by the FCP to provide pre-screening analyses of soils contaminated with uranium, thorium, and radium. The RTRAK Applicability Study (DOE 2004a) documents the capabilities of the NaI systems and provides background technical information supporting the field usage of these instruments. The RTRAK and the other NaI systems acquired data that required several hours of analysis and file manipulation to produce maps showing isotopic activity levels and field coverage. The INEEL has provided integrated engineering services and computer hardware and software support to greatly streamline the data acquisition and analysis process to the point where real-time activity and coverage maps are available to the technicians in the field as the measurements proceed. Online analyses have been added to automatically convert global positioning system data to Ohio State-Plane coordinates, examine and correct stored spectra for energy calibration drifts common to NaI spectrometers, and strip spectra in regions of interest to provide moisture corrected activity levels for total uranium, thorium-232, and radium-226. Additionally, the NaI software performs a number of data quality checks and issues alarms to alert operators when certain data quality criteria have not been satisfied, or that a manual examination of spectral data from a particular area may be required. The HPGe software package provides real-time data analysis of the germanium spectra including a series of automated quality assurance checks that allow personnel to make judgments in the field concerning the adequacy of the data just collected. The FCP has estimated that this technology has produced cost savings in excess of $34M through Fiscal Year 2006.

ADDENDUM 1 FOR VERSION 3.2 TO THE FCP SODIUM IODIDE AND GERMANIUM SOFTWARE OPERATIONS MANUAL - VERSION 3.1

Version 3.1 of the software used by the Real Time Instrumentation Measurements Program (RTIMP) for data acquisition and analysis brought major changes from the prior software version. The updated software underwent a rigorous validation and verification process, and this document was written to describe the operation of the software and the algorithms used in the data analysis routines. While this manuscript was in the final stages of completion, a change was made to the RTIMP equipment inventory, which made it necessary to revise the real time software. The RTRAK system was retired and a fourth Radiation Scanning System (RSS) system was placed into service. Version 3.2 of the real time software was created to remove the RTRAK and any detector-specific parameters and calibration coefficients from the software and to replace them with equivalent parameters for the new RSS4 system. There were no changes from Version 3.1 to Version 3.2 in the way the software operates or in the computational methods and algorithms used for data analysis. Rather than delay the publication of this manual to remove all references to the RTRAK system and insert references to the new RSS4 system, it was decided to insert this Addendum into the manuscript to make the reader aware of these recent changes. Except for numerical values of detector-specific parameters, the reader will gain a proper understanding of the real time software if he or she simply substitutes "RSS4" wherever "RTRAK" appears in the manuscript.

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LIST OF ACRONYMS AND ABBREVIATIONS

AC	alternating current
CD	compact disc
CPS	counts per second
DC	direct current
DLL	dynamic link library
DOE	U.S. Department of Energy
EGAS	Environmental Gamma-Ray Analysis Software
EMS	Excavation Monitoring System
FCP	Fernald Closure Project
FOC	field operations center
FRL	final remediation level
ft/s	feet per second
GPS	global positioning system
HPGe	high-purity germanium (detector)
INEEL	Idaho National Engineering and Environmental Laboratory
K-40	potassium-40
keV	kiloelectron volts
MCA	multi-channel analyzer
MCB	multi-channel buffer
MDC	minimum detectable concentration
NAD83	North American Datum of 1983
NaI	sodium iodide
NI	Nation Instrument
NMEA	National Marine Electronics Association
NPA	net peak areas
OS	operating system
PDOP	precision dilution of position
ppm	parts per million
pCi/g	picoCuries per gram
QA	quality assurance
QC	quality control or quality check
Ra-226	radium-226
ROI	region of interest
RSS	Radiation Scanning System
RTIMP	Real-Time Instrumentation Measurement Program
RTRAK	Radiation Tracking System
TCP/IP	transmission control protocol/internet protocol
Tl-208	thallium-208
Th-232	thorium-232
U-238	uranium-238
USB	universal serial bus
WAC	waste acceptance criteria

FERNALD CLOSURE PROJECT
SODIUM IODIDE AND HIGH PURITY GERMANIUM SYSTEMS
SOFTWARE OPERATIONS MANUAL FOR SOFTWARE VERSIONS 3.1 AND 3.2

1.0 INTRODUCTION

The Fernald Closure Project (FCP), located about 15 miles northwest of Cincinnati, Ohio is a Department of Energy (DOE) facility that formerly produced uranium metal products for America's nuclear weapons program. Because of this mission, soils in the FCP complex are contaminated with radionuclides. Soil contamination originated primarily from airborne dispersion with some contamination from spills and disposal practices between 1952-1989. The FCP employs two types of spectrometer systems for *in situ* evaluation of surface soil contamination, thereby minimizing the need for collection and analysis of soil samples. One type of system consists of mobile sodium iodide (NaI) spectrometers deployed on a variety of platforms. The various NaI systems, [the Radiation Tracking System (RTRAK), the Radiation Scanning System (RSS), and Gator], are used in large-area scanning missions to locate areas of elevated activity, i.e. hot spots, and to verify their complete removal when remedial actions are complete. The Excavation Monitoring System (EMS) provides a similar function for trenches and deep excavations. The second type of system uses high-purity germanium (HPGe) spectrometers, which are capable of providing higher quality, more accurate spectrometric measurements with lower detection limits to confirm the findings of the NaI systems.

The Idaho National Engineering and Environmental Laboratory (INEEL) has developed real-time software systems for the NaI and HPGe spectrometers used at the FCP. These software packages acquire, process, analyze and display spectral and global positioning system (GPS) data. Analysis functions include spectral data processing to obtain counts per second (CPS) in regions of interest, computation of radionuclide concentrations, measurement uncertainties and minimum detectable concentrations, and correction of the computed activity for soil moisture content. The online analysis capabilities of the INEEL software have enabled the FCP to process field data and summarize results more rapidly, allowing remediation activities to proceed immediately after scanning an area, whereas previous FCP data processing systems could take as long as a full day to complete after the conclusion of field data collection activities.

This manual provides installation, configuration and usage guidance for the NaI and HPGe software systems that reside on the RTRAK, RSS, Gator, EMS, and HPGe tripod systems. It also explains the technical bases of the computations used to generate final results from raw spectral data for the various detectors and associated software systems. The manual is divided into several sections pertaining to operation of the NaI software, the HPGe software, analyses and output of the systems, computational basis for all calculations performed by the systems, and a special section devoted to a suite of useful software utilities that aid in the analyses and understanding of the large amounts of spectral data collected at the FCP.

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2.0 SODIUM IODIDE SOFTWARE SYSTEM

The NaI systems deployed by the FCP include the RTRAK, the RSS, the EMS and the Gator. The RTRAK has been in existence since 1994 in a combination of experimental and operational modes (DOE 1999). The software originally developed for this system was written in C and contained little in the way of real-time visual feedback to the RTRAK operator. Data were gathered in a "batch" environment, and then post-processed to compute the radiological activity of the surveyed area. Typically, this process occurred over a 24-hour period. The FCP had a genuine need for a true real-time analysis system where the results of characterization measurements could be placed in the hands of remediation project leaders almost immediately, so that they could assess the progress of their project, and rapidly adjust planned activities to maximize productivity and avoid idle time waiting for scan results.

The INEEL has developed a real-time operating system for the FCP NaI detectors. This software is loosely based on previous work done at the INEEL. This section of the software operations manual describes installation and configuration of the software used to control the NaI systems. This software incorporates real-time functions for acquiring spectral data and position information, processing spectra to obtain counts per second within specific regions of interest, computation of radiological activity, and correction of the computed activity for soil moisture content. New functionality was added in Fiscal Year 2002 to include the gain tracking and scaling algorithms used by the Environmental Gamma-Ray Analysis (EGAS) code originally developed by R.T. Reiman (Reiman 1995 and 1998). Version 3.1 of the NaI software has added additional data analysis capability by introducing the concept of sanding (Reiman 1995 and 1998) to determine spectral background, which had the effect of reducing the minimum detectable concentrations attainable with the NaI systems, as well as increasing the accuracy of radioactivity measurement results.

The major hardware pieces of a typical NaI system are shown in Figure 2-1. A GPS provides vehicle position to the NaI computer through a serial line. The NaI spectrometer and multi-channel analyzer (MCA) hardware communicates with the NaI computer through either a parallel port or a universal serial bus (USB) connection. The RTRAK is deployed from a John Deere tractor where an on-board generator supplies power to the system. The RSS systems are deployed from a self-contained hand-pushed cart where all power is supplied from on-board batteries. The Gator generates on-board power via a direct-current/alternating-current (DC/AC) converter. A typical NaI computer can communicate with a mobile field van using a wireless Ethernet network.

The EMS has a more complicated configuration. The field computer is required for the EMS as it is the main operator interface for the software. It communicates using wireless Ethernet hardware to a monitorless computer located on the end an excavator arm. The excavator-mounted computer performs all data acquisition and control functions including acquisition of the GPS data, ultrasonic sensor and laser stand-off data, and spectral data. The EMS is unique among the Fernald systems in that it is capable of acquiring data with either a sodium iodide or a germanium detector. Generally, the sodium iodide detector is used in a scan mode, while the germanium detector is used in a point-and-shoot mode.

The field van computer displays most of the same information available to the NaI system operator and allows a field supervisor to review the data being collected from a remote location. The field van software displays information obtained from the NaI hardware. It does not perform any calculations or spectral analysis.

The NaI software was written in LabView, which is an object-oriented graphically based software development environment available from National Instruments, Inc. LabView uses the concept of the virtual instrument where a general-purpose computer can mimic the feel and functionality of a real instrument with dedicated controls and displays, and the added versatility of custom software. The LabView environment provides a number of widgets (or tools) that allow software engineers to generate

sophisticated displays, communicate with hardware using all the common protocols (networking, serial lines, GPIB buses, etc.), perform timing functions, and control file handling operations.

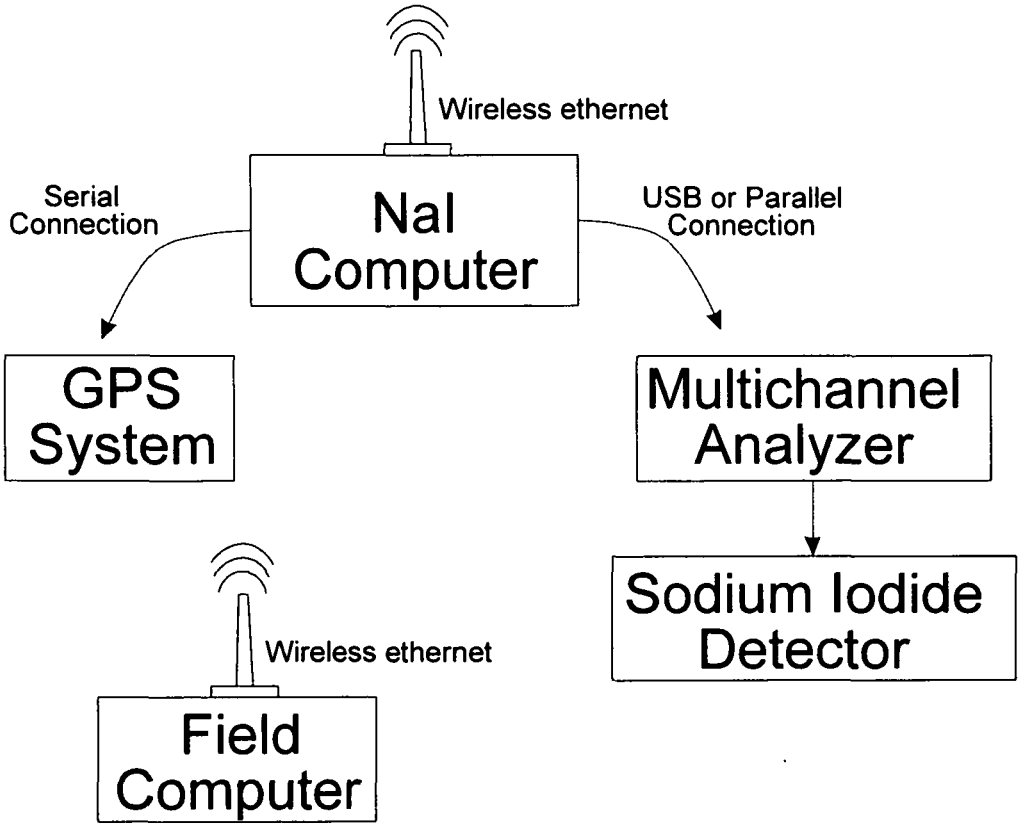

Figure 2-1. Major hardware pieces of a typical NaI system

2.1 Software System Installation

The NaI software requires dynamic link libraries (DLLs) from ORTEC's GammaVision® and National Instruments LabView software systems. The ORTEC libraries are automatically installed when the GammaVision® is installed on the NaI computer (ORTEC). The National Instrument (NI) libraries can be installed from the NI installation disk, or installed as described later in this section. Step-by-step installation instructions are provided below.

- Install GammaVision®[a] using the installation compact disk (CD) provided by ORTEC. This installation should place two DLLs in the *c:\Windows\System32* folder (*c:\WINNT\System32* on Windows2000 machines). These are *mcbloc32.dll* and *mcbio32.dll*. This step can be skipped if GammaVision® is already installed on the machine.

- Install the NI Lab View run-time library. The NI run-time library consists of several files. These can be automatically installed using the provided CD, which contains a WinZip archive of the run-time files. This archive (LV_RT_6-1.zip) will automatically extract the run-time engine to the

a. **Product Disclaimer**

References herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the U.S. Government, any agency thereof, or any company affiliated with the Idaho National Engineering and Environmental Laboratory.

proper location on the hard drive of the NaI computer. All files required for LabView run-time support are placed in the *c:\Program Files\National Instruments\Shared\LabView Run-Time\6.1* folder. These include several DLLs, resource files, and device drivers.

- Install the NaI executable and support data files. The FCP has created a WinZip archive that will automatically extract all software and support files to the proper directories. Extracting the files from this archive will automatically extract and install the NaI executable and supporting data files, placing them in the *c:\FEMP* folder of the NaI computer. The installation will create two subfolders. The *c:\FEMP\GV* folder contains the spectral region of interest (ROI) files needed to derive pre and post operational instrument performance check parameters, which are plotted on control charts.

- Create shortcuts on the desktop of the installation computer as desired for the executables installed. These are the *nai_3-1.exe* and the *nai_van_3-1.exe* executables. Normally, a shortcut for *nai_3-1.exe* should be created on the NaI platforms (i.e., RTRAK, RSS1, etc.). A shortcut for the *nai_van_3-1.exe* is normally made for the field van.

The default configuration files for the NaI systems are shown in Tables 2-1 through 2-5 respectively. These configuration files provide several operating parameters as described by the text in the file including serial port parameters, the upper and lower alarm settings for activities, and Ethernet parameters used to communicate with the field van. In Version 3.1 of the software, seven new entries have been introduced into the configuration files. These are the GPS offset (in feet) from the antenna location to ground level, the detector serial number and calibration date (separated by the "<>" character combination), the multi-channel analyzer serial number, the calibration source used, and three lines containing the field operators and their respective badge numbers. The bottom six lines of the NaI system configuration files are used to set default entries that appear in the universal electronic worksheet when you select a particular NaI detector. They are designed to minimize field typing/data entry into the electronic worksheet. These lines must mimic exactly the text in the "**instrument.cfg**" file for the default settings to function properly.

In the electronic worksheet, the menu selections that appear when you choose any pull-down menu are governed by information contained in the file called "**instrument.cfg,**" and the defaults can be changed as desired by editing that file. This file has been modified in Version 3.1 of the FCP software. The file is divided into four sections. In addition to MCA serial numbers, radiation survey meter serial numbers and calibration dates, check source serial numbers and detector serial numbers and calibration dates, this file also contains an entry for each operator and badge number combination. An example instrument configuration file is shown in Table 2-7. Each section is preceded by an entry that indicates the number of lines in the section. For example, the first section has seventeen multi-channel analyzer identification lines (serial numbers). Serial numbers and calibration dates for the NaI systems should match those in the coefficient file in Table 2-6. Operators and their badge numbers should match data entries used in the system configuration files (Tables 2-1 through 2-5).

Table 2-1. Example RTRAK configuration file

```
0      :com1=0, com2=1
4800   :Baud Rate
5000   :Lower Total CPS Alarm
18000  :Upper Total CPS Alarm
164.0  :Lower Total U ppm alarm
875.0  :Upper Total U ppm alarm
1.5    :Lower pCi/g Th-232 alarm
4.5    :Upper pCi/g Th-232 alarm
1.7    :Lower pCi/g Ra-226 alarm
5.1    :Upper pCi/g Ra-226 alarm
123.1.1.2       : VAN IP address
4800   :TCP Port
9.2    :GPS to ground offset
RTRAK-516<>12-15-2003 : Detector Name and Calibration Date
MCA290                : Multichannel Analyzer Serial Number
RTRAK/GATOR 003       : Daily Check Source ID Number
Dale Seiller/12345    : Operator Name / Badge Number
NA                    : Operator Name / Badge Number
NA                    : Operator Name / Badge Number
```

Table 2-2. Example RSS1 configuration file

```
0      :com1=0, com2=1
9600   :Baud Rate
5000   :Lower Total CPS Alarm
18000  :Upper Total CPS Alarm
164.0  :Lower Total U ppm alarm
875.0  :Upper Total U ppm alarm
1.5    :Lower pCi/g Th-232 alarm
4.5    :Upper pCi/g Th-232 alarm
1.7    :Lower pCi/g Ra-226 alarm
5.1    :Upper pCi/g Ra-226 alarm
123.1.1.2       : VAN IP address
5500   :TCP port
3.83   :GPS to ground offset
RSS1-072198C<>12-15-2003   : Detector Name and Calibration Date
MCA268                     : Multichannel Analyzer Serial Number
RSS 002                    : Daily Check Source ID Number
Dale Seiller/12345         : Operator Name / Badge Number
NA                         : Operator Name / Badge Number
NA                         : Operator Name / Badge Number
```

Table 2-3. Example RSS2 configuration file

```
0      :com1=0, com2=1
9600   :Baud Rate
5000   :Lower Total CPS Alarm
18000  :Upper Total CPS Alarm
164.0  :Lower Total U ppm alarm
875.0  :Upper Total U ppm alarm
1.5    :Lower pCi/g Th-232 alarm
4.5    :Upper pCi/g Th-232 alarm
1.7    :Lower pCi/g Ra-226 alarm
5.1    :Upper pCi/g Ra-226 alarm
123.1.1.2       : VAN IP address
5550   :TCP port
3.83   :GPS to ground offset
RSS2-072198A<>12-15-2003    : Detector Name and Calibration Date
MCA269                      : Multichannel Analyzer Serial Number
RSS 002                     : Daily Check Source ID Number
Dale Seiller/12345          : Operator Name / Badge Number
NA                          : Operator Name / Badge Number
NA                          : Operator Name / Badge Number
```

Table 2-4. Example Gator configuration file

```
0      :com1=0, com2=1
4800   :Baud Rate
5000   :Lower Total CPS Alarm
18000  :Upper Total CPS Alarm
164.0  :Lower Total U ppm alarm
875.0  :Upper Total U ppm alarm
1.5    :Lower pCi/g Th-232 alarm
4.5    :Upper pCi/g Th-232 alarm
1.7    :Lower pCi/g Ra-226 alarm
5.1    :Upper pCi/g Ra-226 alarm
123.1.1.2       : VAN IP address
5600   :TCP port
5.7    :GPS to ground offset
GATOR-OM197<>12-15-2003    : Detector Name and Calibration Date
MCA270                     : Multichannel Analyzer Serial Number
RTRAK/GATOR 003            : Daily Check Source ID Number
Dale Seiller/12345         : Operator Name / Badge Number
NA                         : Operator Name / Badge Number
NA                         : Operator Name / Badge Number
```

Table 2-5. Example RSS3 configuration file

```
0      :com1=0, com2=1
9600   :Baud Rate
5000   :Lower Total CPS Alarm
18000  :Upper Total CPS Alarm
164.0  :Lower Total U ppm alarm
875.0  :Upper Total U ppm alarm
1.5    :Lower pCi/g Th-232 alarm
4.5    :Upper pCi/g Th-232 alarm
1.7    :Lower pCi/g Ra-226 alarm
5.1    :Upper pCi/g Ra-226 alarm
123.1.1.2       : VAN IP address
5650   :TCP port
3.83   :GPS to ground offset
RSS3-082602AZ<>12-15-2003    : Detector Name and Calibration Date
MCA271                       : Multichannel Analyzer Serial Number
RSS 002                      : Daily Check Source ID Number
Dale Seiller/12345           : Operator Name / Badge Number
NA                           : Operator Name / Badge Number
NA                           : Operator Name / Badge Number
```

The NaI coefficient file is also placed in the *c:\FEMP* folder. This file provides the calibration coefficients needed by the NaI and EMS codes to compute activities for the nuclides of interest. FCP personnel update these parameters annually. The April 2, 2003 coefficient file is shown in Table 2-6 for reference.

The coefficient file must follow a specific format. This file contains activity calculation coefficients for the RTRAK, RSS1, RSS2, RSS3, Gator, and the sodium iodide side of the EMS. The coefficients are organized into blocks by deployment platform. The header for each block contains the machine name and serial number followed by the calibration date. These data must be separated by the "<>" character sequence as shown in Table 2-6. The characters in the headers within the coefficient file must be an exact match to this same information in the **instrument.cfg** and **detector.cfg** files (where "detector" is replaced by RSS1, Gator, etc.) in order for the default selection features of the software suite to function properly. In the example table provided, the serial number of the RTRAK is "RTRAK-516" with a calibration date of "12-15-2003". The software keys on the "<>" character sequence to separate serial number from calibration date.

Table 2-6. NaI Coefficient File as of 4/2/2003

```
RTRAK-516<>04-02-2003
0.089429962  0.002221832 -0.000450171  0.0                RTRAK: THci = t1*THcps + t2*RAcps + t3*Ucps + t4
0.157322017 -0.000027750 -0.008899899  0.0                RTRAK: RAci = r1*RAcps + r2*THcps + r3*Ucps + r4
0.212162624 -0.013587640 -0.053182211  0.000744755 0.0   RTRAK: Kci = k1*Kcps + k2*THcps + k3*RAcps + k4*Ucps + k5
4.402204866 -3.130766433 -0.153909238  0.0                RTRAK: Uci = u1*Ucps + u2*THcps + u3*RAcps + u4
13.2066146  -9.392299298 -0.461727715  0.0                RTRAK: Uppm = up1*Ucps + up2*THcps + up3*RAcps + up4
RSS1-072198C<>11-19-2003
0.067484003  0.000176104 -0.000318700  0.0                RSS1: THci = t1*THcps + t2*RAcps + t3*Ucps + t4
0.115945745  0.001551862 -0.006969749  0.0                RSS1: RAci = r1*RAcps + r2*THcps + r3*Ucps + r4
0.185346854 -0.012983808 -0.060864716  0.000226994 0.0   RSS1: Kci = k1*Kcps + k2*THcps + k3*RAcps + k4*Ucps + k5
3.001169057 -2.280970682 -0.120549381  0.0                RSS1: Uci = u1*Ucps + u2*THcps + u3*RAcps + u4
9.003507171 -6.842912047 -0.361648142  0.0                RSS1: Uppm = up1*Ucps + up2*THcps + up3*RAcps + up4
RSS2-072198A<>10-01-2003
0.071997217  0.000683008 -0.000736482  0.0                RSS2: THci = t1*THcps + t2*RAcps + t3*Ucps + t4
0.123063183 -0.001827618 -0.006912053  0.0                RSS2: RAci = r1*RAcps + r2*THcps + r3*Ucps + r4
0.194436182 -0.007603064 -0.065724742 -0.000508517  0.0 RSS2: Kci = k1*Kcps + k2*THcps + k3*RAcps + k4*Ucps + k5
3.652519031 -2.857399920 -0.175895886  0.0                RSS2: Uci = u1*Ucps + u2*THcps + u3*RAcps + u4
10.95755709 -8.57219976  -0.527687659  0.0                RSS2: Uppm = up1*Ucps + up2*THcps + up3*RAcps + up4
GATOR-OM197<>04-07-2004
0.085007284  0.002474490 -0.001246729  0.0                GATOR: THci = t1*THcps + t2*RAcps + t3*Ucps + t4
0.147986045  0.000495047 -0.008756132  0.0                GATOR: RAci = r1*RAcps + r2*THcps + r3*Ucps + r4
0.205794388 -0.009942241 -0.063153668  0.001162094  0.0 GATOR: Kci = k1*Kcps + k2*THcps + k3*RAcps + k4*Ucps + k5
4.521589119 -3.134018835 -0.302969335  0.0                GATOR: Uci = u1*Ucps + u2*THcps + u3*RAcps + u4
13.56476736 -9.402056505 -0.908908005  0.0                GATOR: Uppm = up1*Ucps + up2*THcps + up3*RAcps + up4
RSS3-082602AZ<>12-17-2003
0.074982944  0.001482920 -0.000233306  0.0                RSS3: THci = t1*THcps + t2*RAcps + t3*Ucps + t4
0.119114436  0.000278526 -0.006864669  0.0                RSS3: RAci = r1*RAcps + r2*THcps + r3*Ucps + r4
0.190471809 -0.015338378 -0.052115890 -0.001014666  0.0 RSS3: Kci = k1*Kcps + k2*THcps + k3*RAcps + k4*Ucps + k5
3.764230940 -2.664692785 -0.151538948  0.0                RSS3: Uci = u1*Ucps + u2*THcps + u3*RAcps + u4
11.29269282 -7.994078356 -0.454616845  0.0                RSS3: Uppm = up1*Ucps + up2*THcps + up3*RAcps + up4
EMS-518<>4-07-2004
0.081668020 -0.000084819 -0.000265027  0.0                 EMS: THci = t1*THcps + t2*RAcps + t3*Ucps + t4
0.136872830  0.001298447 -0.007749339  0.0                 EMS: RAci = r1*RAcps + r2*THcps + r3*Ucps + r4
0.192649237 -0.012468695 -0.060373261  0.001276747  0.0  EMS: Kci = k1*Kcps + k2*THcps + k3*RAcps + k4*Ucps + k5
4.038510496 -2.888980504 -0.155898752  0.0                 EMS: Uci = u1*Ucps + u2*THcps + u3*RAcps + u4
12.11553149 -8.666941513 -0.467696256  0.0                 EMS: Uppm = up1*Ucps + up2*THcps + up3*RAcps + up4
Interference Flags
0.20  Dead Time in decimal (i.e. 20%)
```

The sodium iodide portion of the EMS code and the NaI code require the region-of-interest file used by GammaVision to evaluate the resolution and net peak areas of the pre- and post-operational instrument performance check spectra. This file must be placed in the *c:\FEMP\GV* folder and must be named **NaIQC_V2.0.Roi**. This file is a binary file in GammaVision format. GammaVision is called by the NaI and EMS codes. It is operated in a batch format called a JOB file that causes GammaVision to acquire quality control (QC) spectra and report resolution and net peak area calculations.

2.2 GPS Setup

The NaI OS communicates with the FCP GPS system through serial (COM) port 1. The GPS receiver must be configured to provide National Marine Electronics Association (NMEA 1992) output. The GPS units should be configured to provide the $GPVTG and either the $GPGGA or $PNTL,GGK string. The $PNTL,GGK string is provided by real-time differential correcting receivers, and the $GPGGA string is provided by non real-time differential correcting receivers. The GPS unit user's manual should be consulted to enable NMEA strings to the COM port.

Table 2-7. Example instrument configuration file used by the universal worksheet

17
MCA279
MCA269
MCA270
MCA267
MCA268
MCA271
MCA186
MCA188
MCA189
MCA213
MCA214
MCA291
MCA190
MCA212
MCA124
MCA290
MCA176
3
METERC272H<>08-30-2003
METERC003B<>09-30-2003
METERC001B<>10-31-2003
5
Am241#535-2-3;Cs137#535-3-1;Co60#535-3-3
Eu252#535-2-2;Am241#535-2-3;Cs137#535-3-1;Co60#535-3-3
RSS 002
RTRAK/GATOR 003
EMS 004
12
RTRAK-516<>04-15-2004
RSS1-072198C<>11-19-2003
RSS2-072198A<>10-01-2003
RSS3-082602AZ<>12-17-2003
GATOR-OM197<>04-07-2004
EMS-518<>4-07-2004
30687<>09-21-2003
30699<>03-16-2004
31204<>12-22-2003
31265<>12-18-2003
40227<>04-01-2004
40743<>09-03-2003
10
D. Seiller/8533
B. McDaniel/11058
D. Roznovsky/79172
J. Smith/7092
A. Veach/80515
C. Baumann/78329
C. Hopson/77842
S. LeBlanc/76897
J. Nikstenas/77839
NA

3.0 NaI SOFTWARE USE AND MENU SYSTEM

The NaI software provides a menu-driven user interface that guides the user through the set-up and data acquisition process. Figure 3-1 shows the opening menu presented to the operator upon starting the NaI software. (The EMS uses a separate software interface that will be described in Section 5 of this manual.) The user is required to select a deployment platform before proceeding. This is used to select the configuration file and activity coefficients used in the computation of activities and uncertainties. The status window located to the right of the deployment platform selection buttons will display instructions or error conditions as encountered. Errors may be associated with the spectrometer hardware (either not present or not active) or with reading the NaI coefficient file if a problem is detected with the format or content of the file. In this case, the user will not be able to select a deployment platform and the code will terminate after displaying the cause of the error condition.

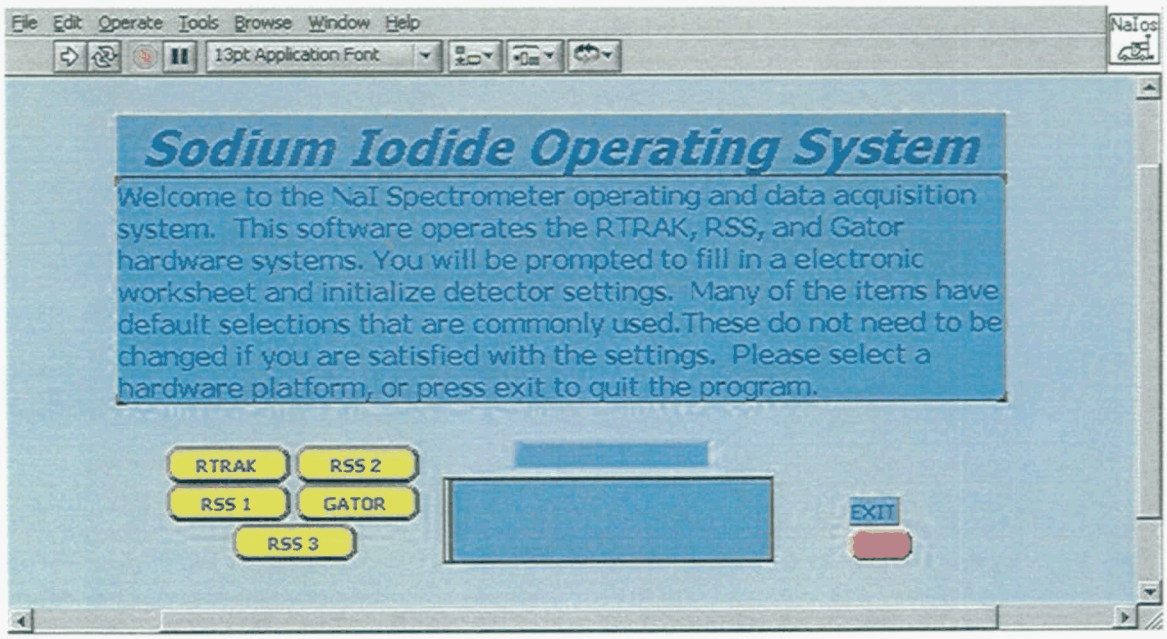

Figure 3-1. NaI operating system opening menu

After selecting the deployment platform, the NaI code prompts the user to either create or select an existing worksheet as shown in Figure 3-2. Electronic worksheets are automatically placed in the *c:\rtrkdata, c:\rss1data, c:\rss2data, c:\rss3data,* or *c:\gatordata* folders of the NaI computer depending on the equipment selection (Figure 3-1). All data associated with a NaI computer are organized by date and batch number. The redesigned electronic worksheet can handle multiple batch numbers, so worksheets are placed in date subdirectories within the vehicle directory. Subdirectories named from batch numbers are created within the date directory. The software creates both date and batch directories automatically.

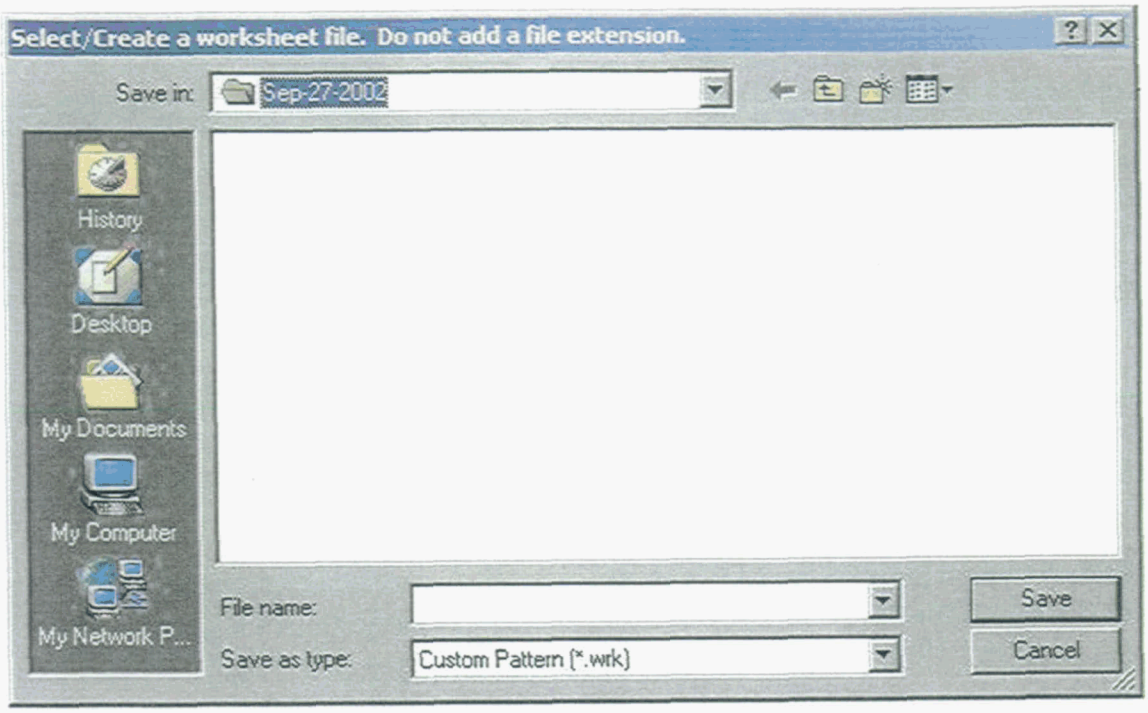

Figure 3-2. Select or create worksheet prompt menu

After an existing worksheet has been selected or a new worksheet has been created, the NaI code will display the worksheet to the user. Because the user has already selected the NaI detector platform, the worksheet will appear with certain default data fields already entered. The detector name/serial number and calibration date, the MCA serial number and the check source ID are read from the file **c:\FEMP\detector.cfg** and entered in the appropriate space on the worksheet. The electronic worksheet is shown in Figure 3-3. It has been substantially revised to provide universal functionality for all FCP gamma spectrometry systems, including the EMS and HPGe systems. The new worksheet takes advantage of the tab control structure introduced in LabView Version 6.0. This allows the user to quickly "tab" between two or more "folders" on a single display, each displaying different information. The general data tab contains the information used to set the acquisition parameters and document the acquisition process. It resembles the Version 1.2 HPGe worksheet in look and functionality in that there is a "batch" section near the bottom of the screen that is designated for data entry for individual acquisitions and/or batches. The upper portion of the general data tab structure includes entries for the data acquisition date, field personnel, equipment serial numbers, instrument calibration dates, and environmental conditions such as temperature and humidity.

The detector serial number and calibration date in **detector.cfg** must be an exact match to one of the entries in **instrument.cfg** and one of the detector headers in the **nai-coef.txt** coefficient file (Table 2-6) so that the software can enter appropriate MCA and check source ID on the worksheet and retrieve the proper coefficients to be used in activity calculations. Data field entries such as detector serial number or multi-channel analyzer serial number can be changed from the default values by selecting other entries from pull-down menus. Caution should be exercised when doing this to ensure proper combinations of detector, MCA and check sources are selected. The pull-down menu entries presented for selection are contained in **instrument.cfg** (see Table 2-7). Gamma dose rate meter serial numbers and calibration dates are read from **instrument.cfg**, whereas default detector serial numbers, calibration dates, MCAs and check source IDs are read from **detector.cfg**. The right side of the universal electronic worksheet screen contains data entry fields to document an independent review of the data associated with this worksheet. The independent reviewer's name must be typed into the "**Reviewed By**" box. The **Review Date**: field can be completed or modified by pressing the "Enter Date" button located

next to the **Review Date** box. Pressing this button will display a series of pull-down menus for month, day, and year, as shown in Figure 3-4.

The "batch data" section includes information specific to the "batch" or data collection location using the FCP naming convention. New "batches" can be added by pressing the **ADD RECORD** button. When this button is pressed, the batch number increases by one and the next record becomes active. If the active record is the first in the worksheet, all fields are blank. If batch data records already exist on the worksheet, the next batch record becomes active and many of the data fields in the new record are populated with values from the previous record. The first record (i.e., record "0") is normally used for the detector pre-operational check, and the batch number fir this is set equal to the numerical spectrum file name. The project name, number and location are used to identify each data set, using standardized FCP terminology for projects. The background activity reading and detector height are used to document the conditions of acquisition. The soil moisture entry directly affects the activity computations as shown in Section 7 of this manual. The batch number, run time and moisture (%) fields must have an entry before the user can begin data acquisition.

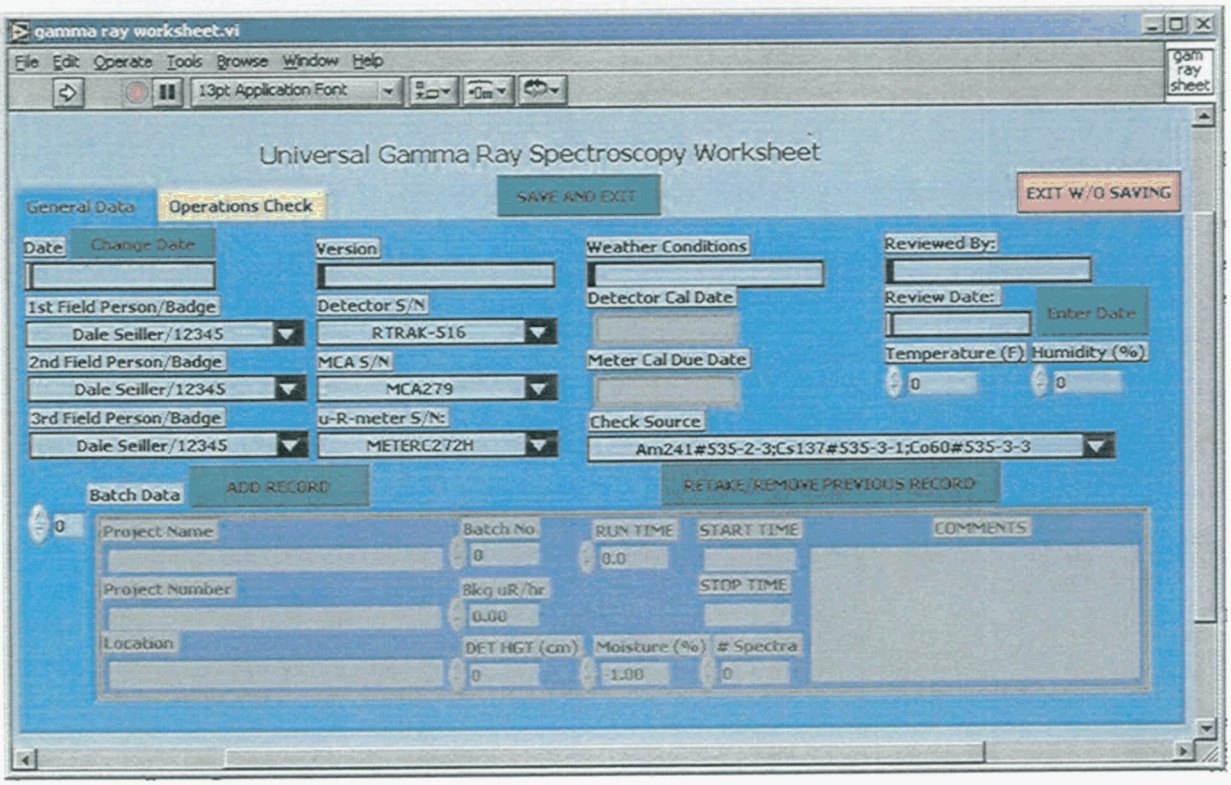

Figure 3-3. Universal gamma-ray worksheet, general data tab

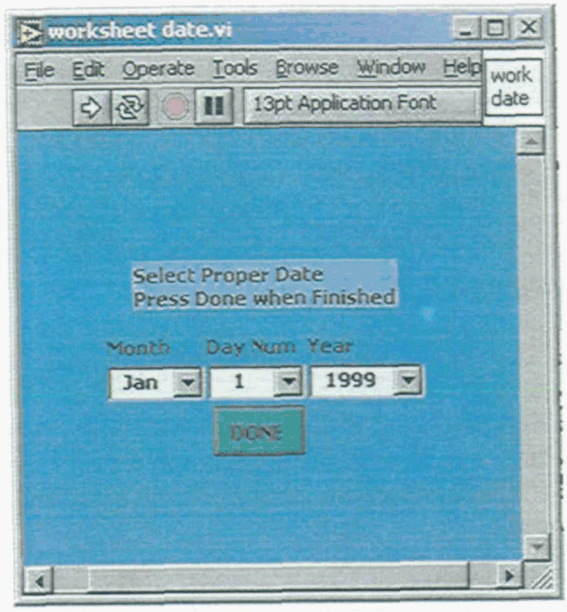

Figure 3-4. Worksheet date entry menu

The batch number is used to create a data directory and as a prefix for the spectral file names. The run time entry in the worksheet sets the preset time used to complete the data acquisition. For NaI spectra, this corresponds to the true time preset. The start time, stop time, and the number of spectra fields are automatically generated by the software. The **Retake/Remove Previous Record** button can be used to remove an erroneous worksheet batch, or used to retake an entire batch due to an unspecified problem. The user will be advised that previously existing data associated with the batch data will be deleted as shown in Figure 3-5.

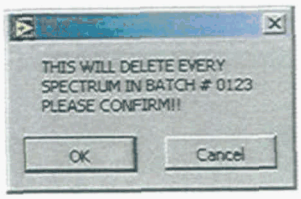

Figure 3-5. Confirmation of batch removal

The Operations Check tab is shown in Figure 3-6. This tab folder contains the pre-operational and post-operational instrument performance checks required by the FCP work procedures. The appropriate spectral energy regions of interest are automatically selected depending on whether NaI or HPGe operations are being performed. For NaI operations, two gamma-ray lines are used, while HPGe operations require three gamma-ray lines. A new feature of FCP real time software Version 3.1 is the ability to import the pre- and post-operational data automatically from the analysis report file into the worksheet. Pressing the **ADD PRE/POST OP DATA** button runs a GammaVision job file that recalls a spectrum, and creates a report file using either a NaI or HPGe ROI file, as applicable, located in the *c:\FEMP\GV* folder. For each peak of interest, the worksheet software extracts the peak centroid channel number, the peak centroid energy, the resolution, and the net peak area from the report file and displays it in the worksheet. In order to complete this action, the user must specify the location and file name of the pre- or post-operational spectrum when prompted for this information.

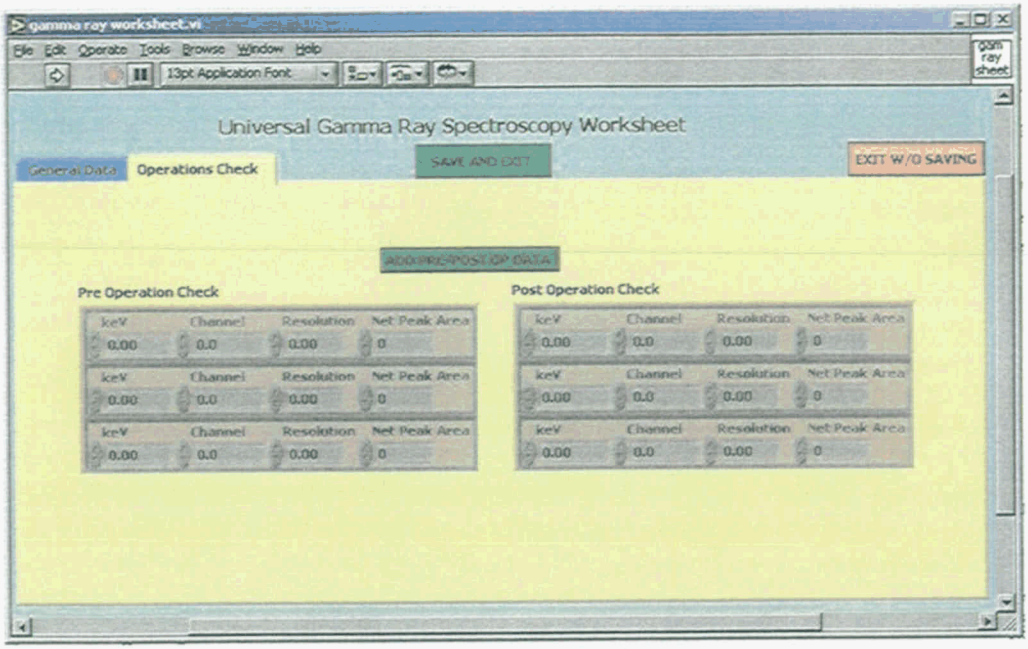

Figure 3-6. Universal gamma-ray worksheet, operations check tab

The user is required to provide a batch number, a moisture value, and a run-time value. The **Moisture %** field is intentionally filled with a -1.0 value, which is invalid. This requires the user to enter a valid moisture value prior to exiting the worksheet. A moisture entry of 0% is considered a valid entry. If any of these three fields are not completed properly, the code displays the warning message shown in Figure 3-7, and will not allow the user to exit the worksheet. Pressing the **SAVE AND EXIT** button saves the worksheet to disk and provides necessary information to the data acquisition modules.

Figure 3-7. Batch data warning message

3.1 Main Acquisition Display

Next, the main NaI data acquisition display is shown to the user. The data acquisition display has been modified to take advantage of the Tab Control structure available with LabView® Version 6.0. Much of the information displayed to the user/operator is placed above the tab folder structure and is available to the user regardless of which folder is selected as shown in Figure 3-8. Most of these widgets are indicators, but there are seven controls. The indicators and controls are described below in order of their appearance on the display from left to right and up to down.

- **Network** indicator. This indicator displays the connect status of the wireless network between the FOC van and the NaI platform.

- **GPS Lock** indicator. This indicator shows the status of the GPS signal.

- **GPS Diff** differential GPS indicator. This indicator shows if differential correction GPS data are available.

- **# Birds** indicator. This indicator displays the number of active satellites used by the GPS.

- **GPS TO** time out indicator. This indicator warns of a GPS signal that is older than 2 seconds.

- **PDOP** precision dilution of position indicator. This indicator shows the current horizontal DOP as reported by the GPS.

- **CPS Alarm** indicator. This indicator alarms when the total gross counts per second exceed the upper limit established in the configuration file.

- **Total U WAC** total uranium waste acceptance criterion indicator. This indicator alarms when the computed total uranium exceeds the upper limit established in the configuration file. This is nominally 875 parts per million (ppm), which is the currently established total U WAC trigger level for most areas.

- **Th-232 FRL** thorium final remediation level (FRL) indicator. This indicator alarms when the computed Th-232 activity exceeds the upper limit established in the configuration file. This is nominally 4.5 picoCuries per gram (pCi/g), which is three times the normal Th-232 FRL.

- **Ra-226 FRL** Radium final remediation level indicator. This indicator alarms when the computed Ra-226 activity exceeds the upper limit established in the configuration file. This is nominally 5.1 pCi/g, which is three times the normal Ra-226 FRL.

- **Dead T** dead time alarm. This indicator alarms when the spectrometer dead time exceeds the value established in the configuration file (nominally 20%).

- **Avg Cal** summed spectrum calibration alarm. This indicator alarms when the summed spectra energy calibration does not meet specification as described in Section 5 of this manual.

- **Sng Cal** single spectrum calibration alarm. This indicator alarms when a single spectrum energy calibration does not meet specification as described in Section 5 of this manual. This alarm is for information only as the single spectrum calibration is not used for any computations.

- **Northing** indicator. This indicator provides the current northing value in Ohio State plane south coordinates.

- **Easting** indicator. This indicator provides the current easting value in Ohio State plane south coordinates.

- **Alt (ft)** altitude indicator. This indicator provides the current elevation above mean sea level.

- **Van Write** control. This control toggles the network transmission between the NaI system and the FOC van on or off.

- **PAUSE** control. This control pauses the current data acquisition. A Draw Coverage sequence is started when this control is pressed.

- **CLEAR DISPLAYS** control. This control clears all data from the display buffers.

- **EXIT** control. This control ends data acquisition and exits the program. The current acquisition is allowed to complete before the program exits to the electronic worksheet where the operator can add any final comments.

- **PDOP preset** control. This control sets the PDOP alarm level. It defaults to 6.

- **END RUN/NEW BATCH** control. This control ends the current batch, opens the worksheet and allows the operator to start a new batch without leaving the software.

- **True Time** indicator. This shows the current true time of the spectrometer.

- **Live Time** indicator. This shows the current live time of the spectrometer.

- **Speed (ft/s)** speed indicator. This indicator displays the ground speed in feet per second provided by the GPS hardware. This is the average speed over two GPS readings.

There are three tab folders in the NaI data acquisition menu. The Gator/RSS folder is shown in Figure 3-8. The main X-Y chart shows the current data in Ohio State Plane South coordinates. The user may select whether total uranium, Th-232, Ra-226, or the total gross count rate data are displayed as the data acquisition proceeds. The set of controls just above the X-Y graph can be used to make this selection. The software defaults to displaying the total uranium. The chart legend located to the right of the X-Y chart provides visual feedback as to which nuclide is displayed on the map. This panel also provides the percentage dead time and the current spectrum file name. The channel location of the 2614.6 keV (Tl-208) peak, which is used for automated energy calibration purposes, is provided as a quick visual confirmation of the energy calibration. This is provided in the **Single Cal 2614.6 Peak Centroid** indicator and should stay within 15 channels of channel 447. Also, a digital display of the current chart value is provided in the **Chart Value** indicator. This display panel is designed for an 800 × 600-resolution monitor and will fill the entire monitor area of the RSS and Gator computer screens.

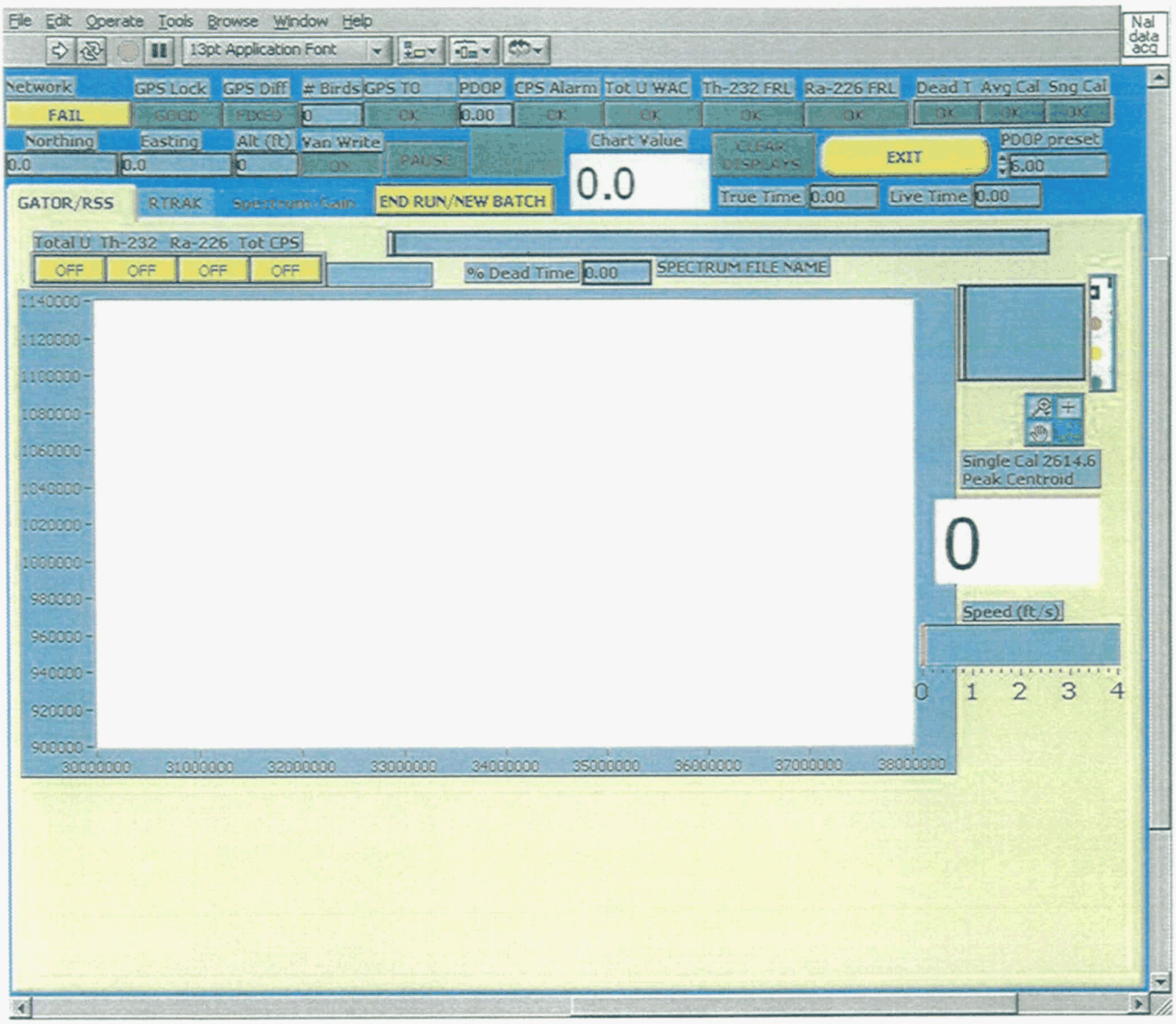

Figure 3-8. Gator/RSS tab folder of the main NaI data acquisition display

The RTRAK tab folder is shown in Figure 3-9. It is a duplicate of the Gator/RSS display, but is designed to fit on a 1024×768 resolution monitor. This is more suitable to the RTRAK computer hardware. The RTRAK and Gator tabs are completely independent of each other and can be set to monitor different nuclides. The RTRAK X-Y chart defaults to displaying total uranium concentration.

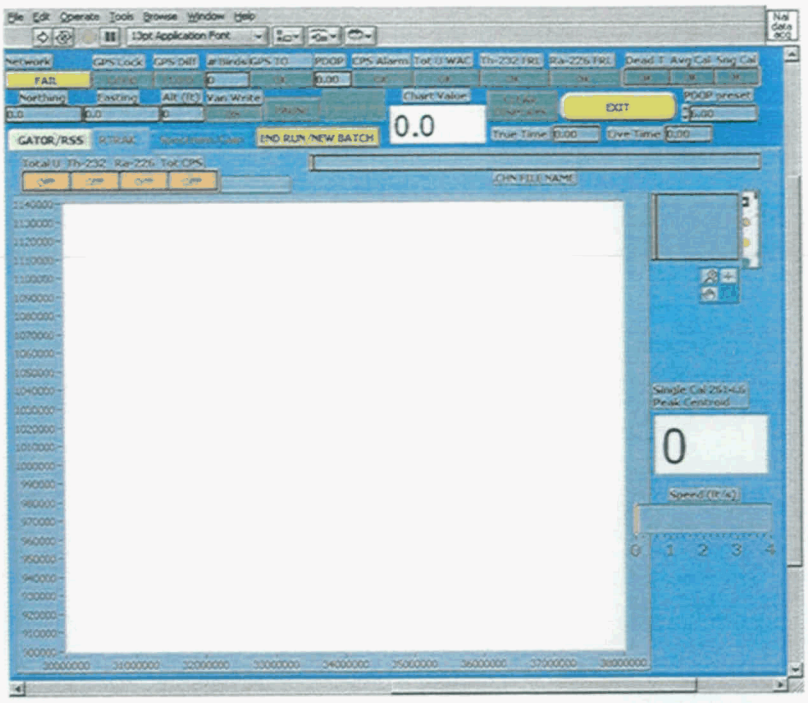

Figure 3-9. RTRAK Tab Control display

The Spectrum/Gain tab folder is shown in Figure 3-10. This folder shows the summed spectra used to generate the energy calibration data. The gain stabilization window shown directly beneath the spectrum display shows a view of the summed spectra expanded about the 1460 keV potassium-40 (K-40) energy line.

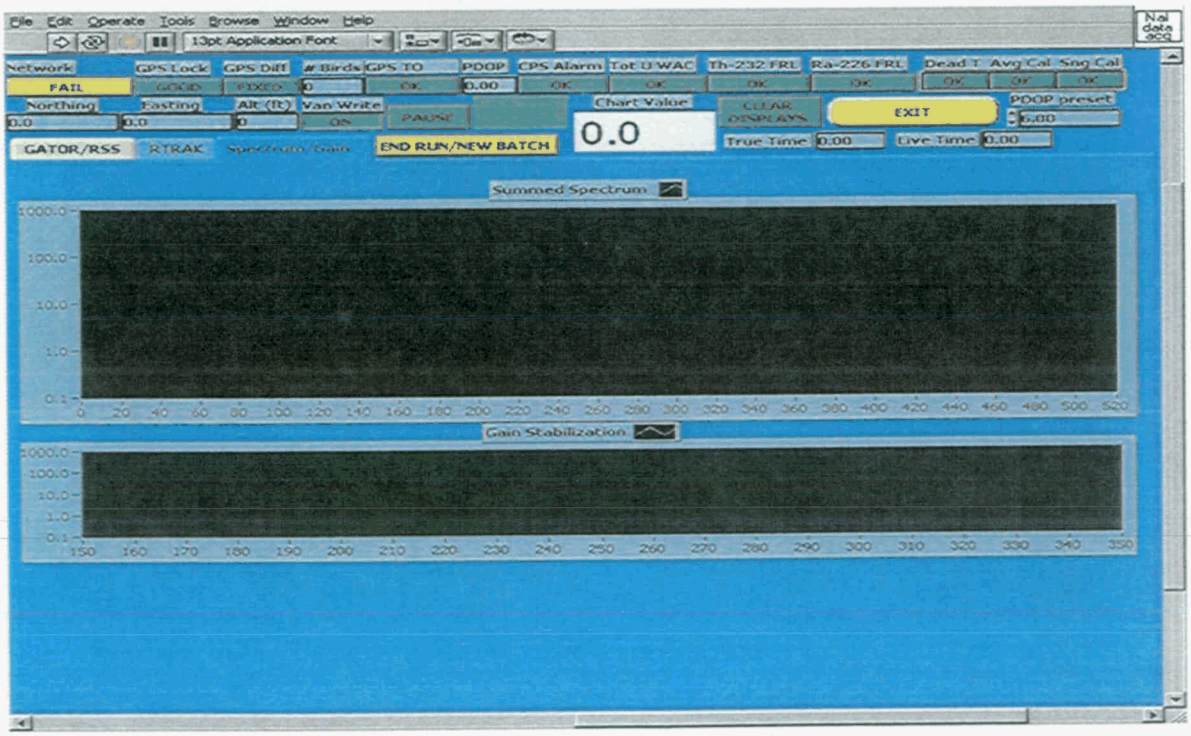

Figure 3-10. Spectrum/Gain tab folder

If the **PAUSE** button is pushed during the acquisition process, the program pauses data acquisition and displays a scaled coverage plot like that shown if Figure 3-11. The scaled coverage plot is created from the NaI log file by drawing a series of 15-foot wide filled-in rectangles where the centerline of each rectangle corresponds to consecutive data points in the log file. The width of the rectangular symbols on the graph is equal to the diameter of the field-of-view of the NaI detector as determined by R.T. Reiman and reported to the FCP in 2004. If there is a printer connected to the system, the operator has the option of printing the coverage plot by pressing the "**PRINT & EXIT**" button.

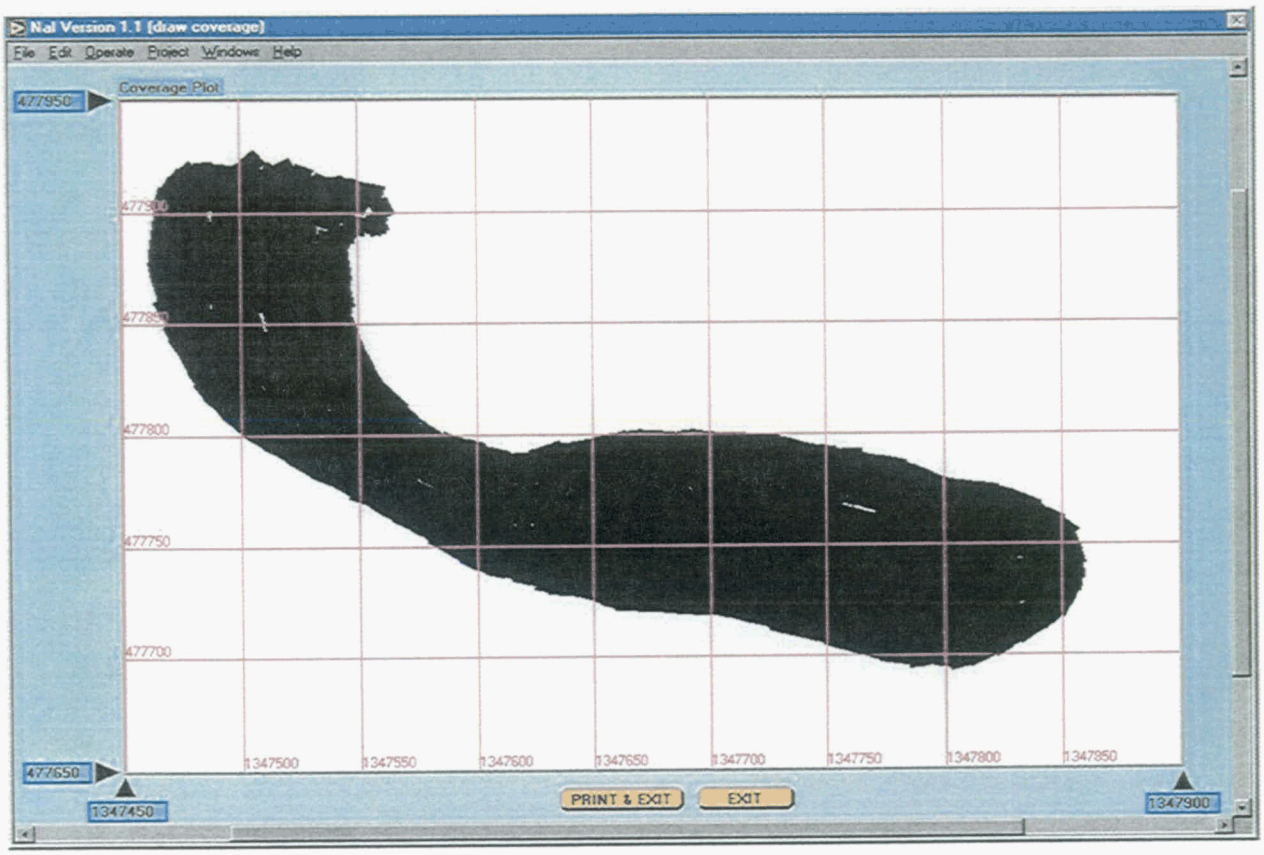

Figure 3-11. Example scaled coverage plot display

Once the EXIT or PRINT&EXIT button is pressed, the software will advise the operator that it is in a paused state as shown in Figure 3-12.

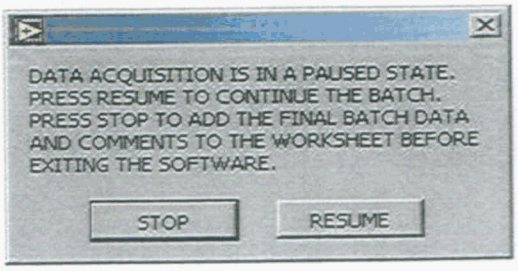

Figure 3-12. Prompt indicating that the NaI software is in a paused state

3.2 NaI Van Software Operation

Real-time quality assurance (QA) and monitoring of all NaI operations is available remotely from the Field Operations Center (FOC) van, if desired. All software required to operate the field van is automatically installed on the field van as described in Section 2.1. The executable for the NaI field van operation should be installed as **nai_van_3-1.exe** in the *c:\FEMP* folder. This code does not process any data. It receives a copy of the NaI log file generated on the NaI platform through a wireless Ethernet connection, and parses each record to build the van display. A duplicate copy of the NaI log file is placed in the *c:\vandata\<date>\<batch number>* directory on the field van computer. A brief description of the software operation is provided below.

Open the program by double-clicking on the NaI_Van icon. This will display the opening menu shown in Figure 3-13. The van operator must select the platform that is to be monitored.

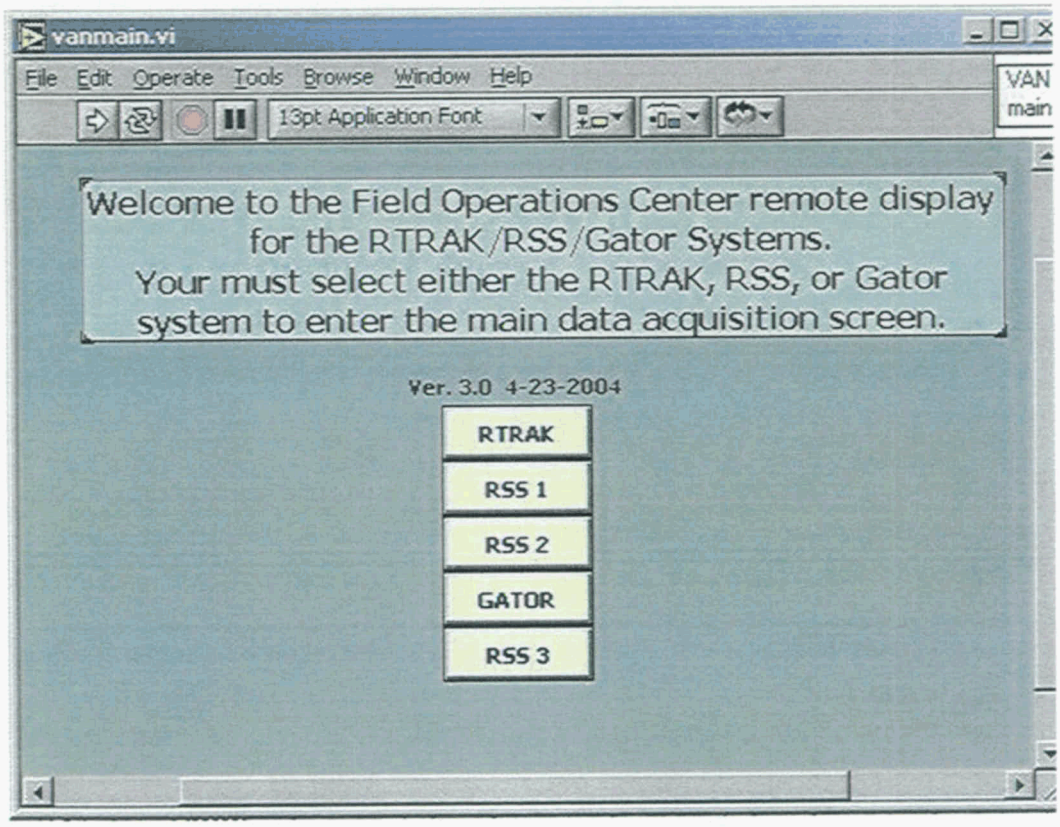

Figure 3-13. NaI FOC main menu display

Once a platform is chosen the main van operations screen shown in Figure 3-14 is displayed to the van operator. The layout and function of the field van main data display is similar to the main data display on the NaI platform. Controls are provided to select the nuclide activity to display on the large X-Y map plots. The two maps operate independently of each other and can display total uranium, thorium, radium or gross count rate. Pressing the **DRAW COVERAGE** button will provide a scaled coverage map of the data similar to that shown in Figure 3-11. The **CLEAR DISPLAY** button erases the map display contents allowing them to build anew. Pressing the **STOP** button will terminate the program.

Alarms and indicators for the GPS, total counts per second, total uranium, thorium and radium activity are located across the top of the display. A speedometer is provided to show vehicle speed. On the left side of the screen, above the X-Y map there are also alarms to indicate if the percentage dead time

exceeds 20% and if there is a problem with the automatic energy calibration related to either the 17 spectra summed energy calibration, or the single spectrum calibration check. Digital indicators for Ohio State Plane coordinates easting, northing, and altitude are provided above the X-Y maps. The **STATUS** indicator shows the operational mode of the NaI platform (ACTIVE, PAUSED, etc.). The **HARDWARE** indicator shows the NaI platform name.

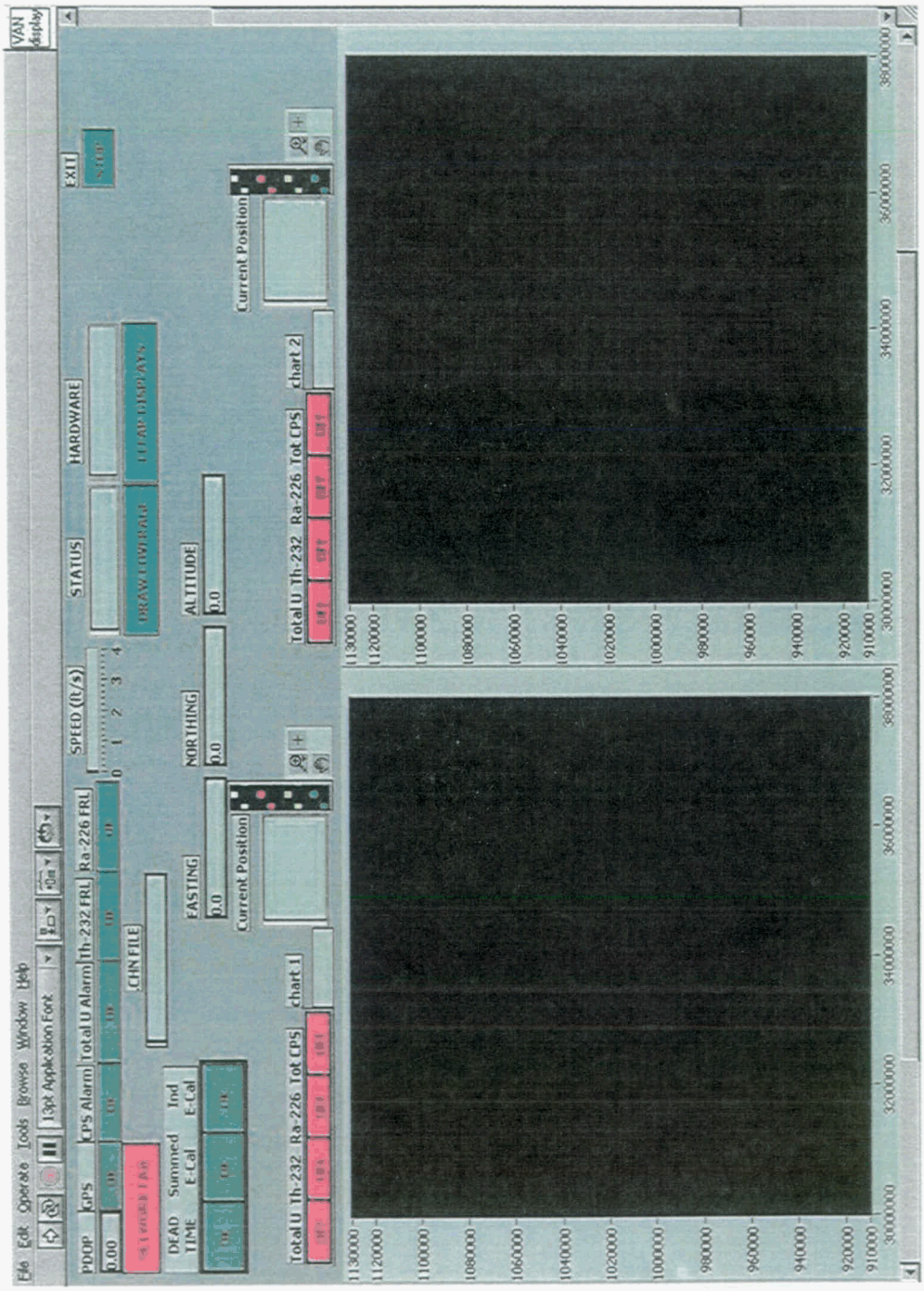

Figure 3-14. Main data display for the NaI van software

4.0 HIGH PURITY GERMANIUM SOFTWARE SYSTEM

Major changes in the capabilities and operation of the HPGe software system have been made from Version 2.0 to Version 3.1. The HPGe software system documentation has not been revised since its initial release in 1998. At that time, the HPGe software documentation was a separate document from the NaI documentation. This section of this document merges the HPGe and NaI software documentation and describes the current capabilities and operation of Version 3.1 of the HPGe software.

4.1 HPGe Software Configuration

The HPGe software executable requires four support files (and several EGAS support files described below) for proper operation. It also assumes that GammaVision has been properly installed on the HPGe computer as described in Section 2 of this document. The installation and location of executables and support files for the HPGe software are summarized in the following paragraphs.

Install the HPGe software using the FCP installation scripts. This will automatically extract several files to the *c:\FEMP* folder, the *c:\FEMP\GV*, and the *c:\FEMP\EGAS* subfolders of the FEMP folder. The **hpge_v3-1** executable and a sample configuration file will be placed in the *c:\FEMP* folder. A sample HPGe configuration file is provide in Table 4-1. The first line in the configuration file is the serial port number that the GPS unit is connected to on the HPGe computer. The second line specifies the baud rate at which the GPS unit transmits data. The third line is the default detector number and calibration date of the detector. The detector number and calibration date must be separated by a greater than and less than sequence of characters as shown in the example. The fourth line is the MCA serial number used with the HPGe detector. The fifth line is the serial number of the calibration check source. The sixth line is the distance from the GPS antenna to ground level and is used to compensate the GPS data to obtain accurate elevation data. The last three lines are the default names and badge numbers of the analysts who operate the HPGe detectors. If there is only one default operator assigned to an HPGe systems, the other two operator slots should be labeled as **N/A**. The default values specified in the HPGe configuration file, **hpge.cfg**, are used to populate the universal worksheet fields. This minimizes the time and effort required to complete data entry onto the worksheet during field operations.

Table 4-1. Example HPGe configuration file

```
0      :com1=0, com2=1
9600   Baud Rate
30904<>10-25-2002
MCA291
Am241#535-2-3;Cs137#535-3-1;Co60#535-3-3
8.0  :GPS to ground offset
Dale Seiller/12345
NA
NA
```

In addition to the configuration file, the **HPGE.CLB** file will be put in the *c:\FEMP* folder and the **HPGEWIDE.ROI** region-of-interest file will be placed in the *c:\FEMP\GV* folder during the installation process. These files are generated by the Real Time Instrumentation Measurement Project (RTIMP) personnel and are used by the **hpge** software and the universal worksheet when setting the default energy calibration of the system and the default ROIs needed to extract peak resolution and net peak areas from the peaks in the pre- and post-operational performance check spectra.

The **apriori.txt** file is an ASCII text file used when assessing the precision of duplicate measurements. It consists of a list of paired entries in each record of the file. The first part of each record is the isotope of interest and the second entry is the *a priori* MDC of the isotope. The two entries are separated by a "<>" character sequence. The isotope names must match exactly the names used in the EGAS report file.

In the past, FCP analysts used to enter nuclide activities for the isotopes of interest directly from an EGAS report file into a MicroSoft Excel® spreadsheet. The spreadsheet performed a series of calculations and checks of the consistency between multiple gamma-ray lines of Th-232, Ra-226, and uranium-238 (U-238). It also checked the consistency of the reported isotopic activities between the original and duplicate measurements when a second spectrum was collected at a single location. The FCP RTIMP data reduction procedure describes the conditions that must be tested when comparing an original and a duplicate spectrum. Different acceptance criteria are used for the duplicate check depending on whether a consecutive or nonconsecutive duplicate analysis was performed, and whether the isotopes of interest in the original and duplicate spectra are above or below the minimum detectable concentration (MDC), and also above or below five times the MDC. Version 3.1 of the HPGe software performs all of these duplicate checks automatically. Table 4-2 shows the most recent default isotopic MDC values (in pCi/g, ppm for total U) that are used in the duplicate comparison. They are stored in the HPGe software in a user editable file called **apriori.txt**.

Table 4-2. Default apriori.txt file

7
K- 40<>1.300
Ra 226<>0.140
Th 230<>60.00
Th 232<>0.150
Total U<>8.600
U- 235<>0.170
U- 238<>2.900

A specialized executable that contains a subset of the EGAS analysis software and required support files will be placed in the *c:\FEMP\EGAS* folder. The **egas_sub.exe** executable is a minimal version of the EGAS software package designed to operate from a batch file generated by the HPGe software. The full EGAS software package is designed as an interactive spectral analysis package that gives the user many analysis options. The **egas_sub** executable is designed to analyze virtually all of the spectra that will normally be encountered in the Fernald field environment. It has been automated in that it reads an input file created by the HPGe software to specify analysis options and spectra. In addition to the executable, the **egas_sub** software requires information about the efficiency of the various HPGe detectors in use at Fernald, and the nuclides of interest. The detector efficiency files have "**.cfh**" and "**.daa**" extensions. The **DETID.TXT** file contains a list of all valid HPGe detectors in use at the FCP. The KUT.LST file contains the nuclides to be searched for in the spectra. The user should consult the EGAS user's manual and software documentation for further information concerning the operation and configuration of this software.

4.2 HPGE Software Operation

The *in situ* HPGe software is designed to provide a visual display of the spectrum as it is collected, while integrating GPS information and automating the spectral analysis in near real-time by calculating

and displaying activities for specified nuclides. The main panel display for the HPGe system is shown in Figure 4-1. Once the software has verified the connection of a valid detector, it will prompt the user to create a new worksheet or open an existing one. The sequence of prompts is the same as that shown in the previous chapter, Figures 3-2 through 3-6. Data entered into the worksheet establishes acquisition and analysis parameters such as detector ID, detector live time, soil moisture, spectrum file name, and data collection location ID. The spectrum file name and spectrum file header both contain the location ID as a means of uniquely linking the spectrum to a particular sample area (using standardized FCP project and area names). The location ID with a "-D" suffix also denote when a spectrum is a duplicate measurement. Prior to exiting the worksheet (in HPGe mode only) the operator will be prompted to verify the ID number of the HPGe detector to be used, as shown in Figure 4-2. This prompt appears if the worksheet is newly created as described here or is created using the worksheet editor as described in Section 8.3. If the operator has recalled an existing worksheet, created from an earlier operation, the prompt in Figure 4-2 does not appear.

After the worksheet is properly filled in, the system is ready to acquire data. The operator is asked to verify that the GPS unit is operating properly as shown in Figure 4-3. At this point, the GPS unit should be continuously updating position and GPS system status. Once the operator presses the continue button, the system records the GPS data and starts the spectrometer. The operator also has the option of aborting the HPGe system prior to collecting any spectra by choosing the "**ABORT HPGE SOFTWARE**" button

The HPGe software display and associated controls (Figure 4-1) are considerably simpler than that of the sodium iodide software. The upper part of the main HPGe panel display contains GPS related indicators. The **GPS Lock** indicator should be green when the GPS unit is receiving satellite data. The **GPS Diff** indicator is green when the GPS signal is differentially corrected. The **GPS TO** indicator is red when the satellite has not updated the GPS signal in three or more seconds. The **PDOP** indicator provides a measure of GPS accuracy. The **Northing**, **Easting**, and **Alt (ft)** indicators provide Ohio state plane south coordinates updated every second. Underneath the location coordinates, are the detector dead time, the live time, and the current gross count rate across the entire spectrum. Underneath these indicators are the **Spectrum Sample Description** and the spectrum file name. The spectrum sample description is in a specific format, which is: detector ID, location ID, northing, easting, altitude, <detector height in centimeters>cm, M:<soil moisture in decimal format>. This format is slightly different from that used by the sodium iodide software. The detector ID is used by the EGAS analysis code to select the proper detector efficiency, and the location ID string is used to uniquely tie the spectrum to a particular project and location on the FCP site. The spectrum file name is displayed next to the sample description and should match the batch number entered in the worksheet. The spectrum will be updated and displayed approximately every second in the large X-Y display that occupies most of the bottom portion of the main display panel. The spectrum axis is marked in energy units based on the energy calibration information stored in the **HPGE.CLB** file that is located in the *c:\FEMP* folder.

Other than the interactive prompts (where the operator must acknowledge a condition or option), the HPGe software has only one control on its front panel. This is the HPGe abort button. This can be pressed at any time during an acquisition to abort the spectrum acquisition process. If this button is pressed, the software will stop the spectrometer, write the spectrum to disc, and analyze the spectrum as if it had gone through a normal completion. If this spectrum was aborted due to an operator error in the initial conditions, it can be removed automatically in the worksheet as described in Section 8.3 of this document. This action will remove both the spectrum and any reference to the spectrum in the worksheet. It will not remove the aborted spectrum from either the summary or the report file.

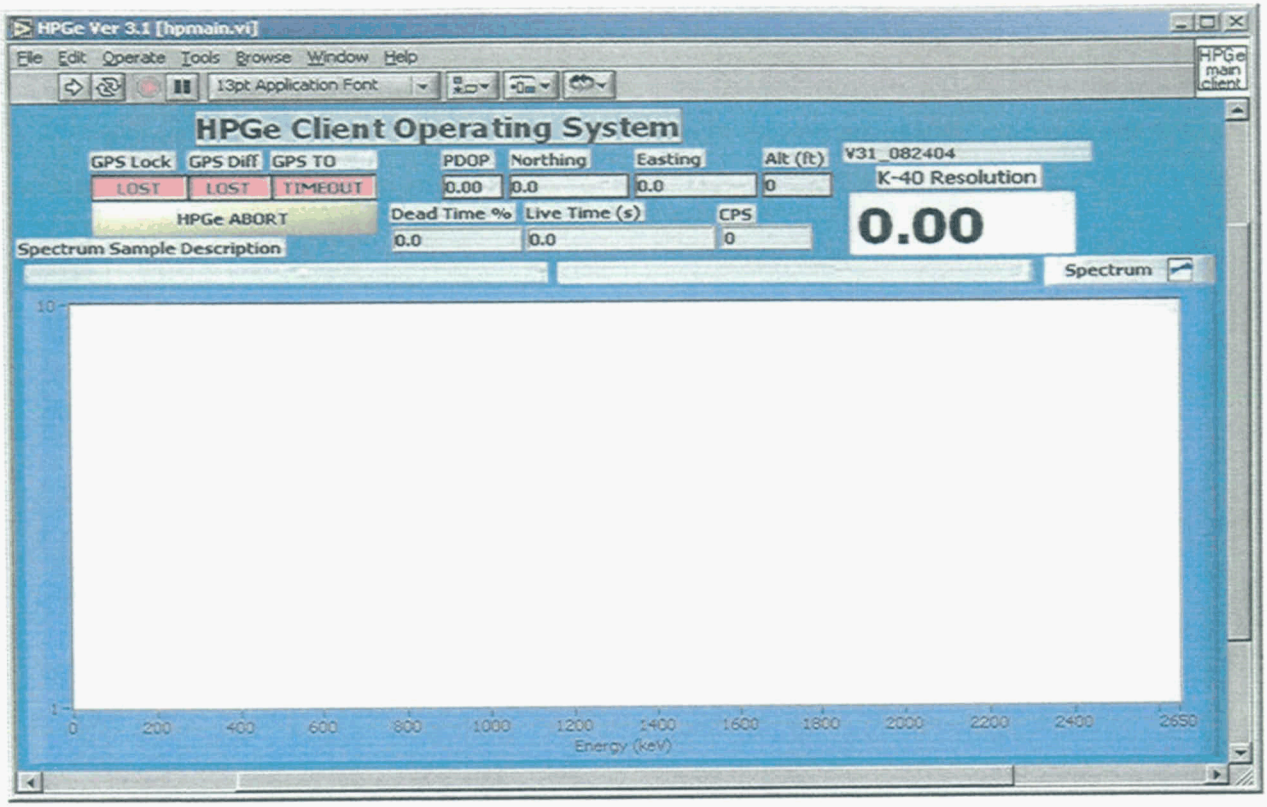

Figure 4-1. HPGe field detectors main panel display

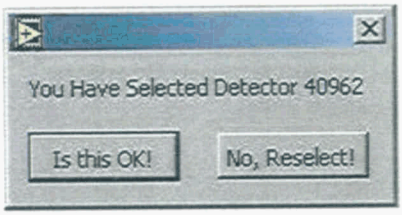

Figure 4-2. HPGe confirm detector number prompt

Figure 4-3. GPS ready prompt

Once the spectral acquisition has reached its normal termination, the spectrum is analyzed by a simplified version of the EGAS spectral analysis software package. The K-40 peak resolution value reported by EGAS will be displayed in the K-40 Resolution indicator shown in Figure 4-1, and the calculated activities for total uranium, radium, and thorium will be displayed in a pop-up window. In the event that the on-line simplified EGAS code could not analyze the spectrum, the operator will be notified

of the failure as shown in Figure 4-4. EGAS performs a number of analyses such as automated energy calibration, spectral stripping, and activity calculations. One of the more common reasons for the simplified EGAS code to fail during the analysis phase is if one or more of the key gamma-ray lines used by the automatic energy calibration algorithm is missing.

Figure 4-4. EGAS analysis failure notification

If the spectrum collected is a duplicate spectrum, the HPGe software will ask the operator if it is a consecutive duplicate. When determining the acceptability of duplicate measurements, the acceptance criteria for consecutive duplicates are more stringent than those for non-consecutive duplicates. This prompt is shown in Figure 4-5. Finally, after the data acquisition and analysis tasks are complete, the HPGe software asks the operator to either collect another spectrum, or to shut the software down as shown in Figure 4-6. Pressing YES repeats the sequence described herein starting with the universal gamma-ray worksheet.

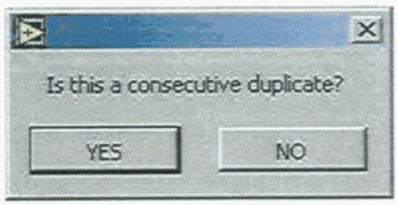

Figure 4-5. Duplicate spectrum prompt

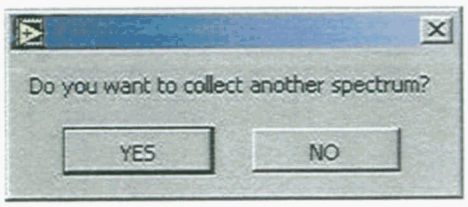

Figure 4-6. Prompt to collect another spectrum with the HPGe software

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5.0 EXCAVATION MONITORING SYSTEM

The Excavation Monitoring System (EMS) is a collection of computer, positioning system, multi-channel analyzer, and radiation detector hardware mounted and deployed from the end of a standard track-style excavator. The EMS allows remediation analysts to examine trenches and pits for radiological contamination without actually entering these areas. The EMS was originally developed in 1996 for in-house applications at the INEEL. The original INEEL design included a linear actuator that maintained a constant offset between the EMS detector and the ground surface by using a laser rangefinder to provide feedback to the linear actuator controller. In Fiscal Year 2001, the INEEL redesigned the EMS for the FCP to make it lighter, smaller, and less complex. The redesign focused on removal of the linear actuator and associated controller/power supply. This reduced the EMS weight by 50% and eliminated the need for an AC generator on the excavator. It was delivered to the FCP during the summer of 2001.

The real-time software operating system for the EMS hardware is closely related to both the NaI and HPGe software discussed earlier in this manual. They share many common modules. The EMS can acquire both NaI and HPGe spectra in both a scan and a point-and-look fashion. The EMS system is designed to use a GPS to acquire position data. Unlike the other FCP real time gamma detection systems, the computer hardware and gamma detector are mounted on the end of an excavator arm and must be controlled from a remote FCP field computer. Figure 5-1 shows a basic block diagram of the EMS system hardware.

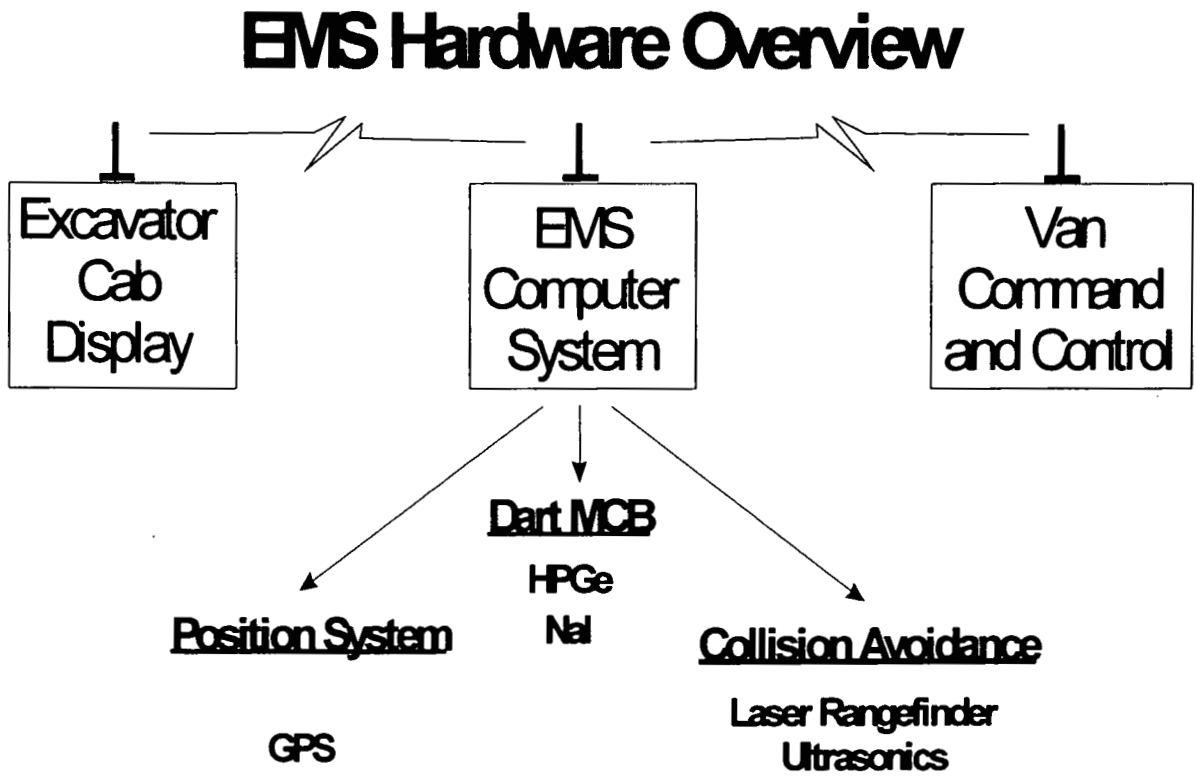

Figure 5-1. EMS hardware block diagram

5.1 The EMS Operating System

The EMS operating system is comprised of three separate executables running on three separate computers, and communicating via transmission control protocol/internet protocol (TCP/IP) over wireless 802.11b Ethernet hardware. The FCP analyst interacts with the data acquisition equipment on the EMS by issuing commands from a remote computer, often referred to as the control van console or simply the control van, although it is not always housed in a van. A monitorless computer that resides at the end of the excavator arm, called the EMS computer, is programmed to execute commands issued from the EMS control van computer. The EMS computer directly controls all sensor hardware located on the excavator. It also stores GPS and spectral data and sends data packets to both the control van and the excavator cab computer. These data transmissions enable the excavator operator and the real time analyst to view the progress of the survey in real time on computer screens in the excavator cab and the van. The excavator cab computer displays area coverage and other pertinent operational information to the excavator operator. Operational data include critical parameters such as ground speed and sensor elevation. A short start-up guide that provides a procedural based approach to setting up and running the EMS is provided in Appendix A.

5.1.1 Installing the EMS Operating System

A complete installation of the EMS operating system requires installation of executables and support files on the three computers shown in Figure 5-1. Each installation is individually described below in its own subsection. Since the EMS and excavator cab computers do not have CD-ROM drives, the CD-ROM on the control van computer may be used in conjunction with the wireless network to install operating system software on the remote computers by enabling shared access to the CD-ROM drive on the control van computer.

5.1.1.1 EMS Excavator Arm Software Installation

The EMS computer that resides on the excavator arm is not normally connected to a monitor, keyboard, or mouse. To connect these peripherals, remove the top cover of the EMS tool and connect to the industrial computer chassis located directly underneath the cover of the EMS. Follow the steps described below.

- Install GammaVision® on the EMS computer using the installation steps described in the GammaVision® installation manual. See Section 2.1 of this manual.

- Install the ComputerBoards Instacal software provided with the ComputerBoards PCI-DAS1000 data acquisition card. Using the Instacal software, configure the card as board #1 using single-ended input. (This step is needed only if a complete re-install is required on a fresh hard disk.)

- Install the **EMS_3-0** executable. This FCP auto-install zip file will automatically create a *c:\ems* and a *c:\arcsecond* folder and place all required files in appropriate directories on the EMS excavator computer. Install the LabView 6.1 run-time support files using the file named **LV_RT_6-1.zip**.

- Create a shortcut to the **ems.exe** and **shut_ems.exe** programs in the *c:\windows\start menu\programs\start up* folder. Programs placed in this folder of a Windows 98 machine will automatically start as the computer boots.

5.1.1.2 EMS Control Van Computer Software

The EMS control van computer software acts as the main analyst interface for all data acquisition hardware and sensors on the excavator arm. The control van software can be installed using the following steps.

- Install GammaVision® as described in Section 2.1 of this manual.
- Follow the installation procedure for the NaI software suite. Install the **ems_van_3-1.exe** executable in the *c:\FEMP* directory as described in Section 2.1
- Install the LabView run-time engine as described in Section 2.1.

5.1.1.3 Installation of the EMS Excavator Cab Software

The excavator cab software is merely used to display coverage and collision proximity information to the heavy equipment operator in the cab of the excavator. It is the least complex of the three executables making up the EMS software suite. To install the excavator cab software, perform the following steps.

- Install the **ems_cab_3-0** zip file. This zip file will automatically create a *c:\ems* folder and place all required excavator cab files in it.
- Install the LabView run-time engine as described in Section 2.1.
- The TCP/IP protocol must be active and the network address of the excavator cab must be 123.1.1.23.

5.1.2 EMS Configuration Files

One configuration file (**ems.cfg**) and three support files are needed to run the control van software. The calibration coefficients for NaI activity calculations are contained in the support file **nai-coef.txt**. The default energy calibration for HPGe detectors is stored in **hpge.clb**. The third support file, **apriori.txt**, contains the *a priori* HPGe MDCs that are used when judging the acceptability of duplicate measurements. The user can edit these files so that alarm settings, calibration coefficients for the NaI detectors and HPGe MDCs may be updated. The EMS alarm setting configuration file establishes upper and lower warning levels for soil radioactivity measured by a NaI detector. These alarm levels are related to FCP regulatory or action levels. An example EMS configuration file is shown in Table 5-1.

Table 5-1. Default EMS configuration file

```
5000  :Lower Total CPS Alarm
18000 :Upper Total CPS Alarm
246.0 :Lower Total U ppm alarm
875.0 :Upper Total U ppm alarm
1.5   :Lower pCi/g Th-232 alarm
4.5   :Upper pCi/g Th-232 alarm
1.7   :Lower pCi/g Ra-226 alarm
5.1   :Upper pCi/g Ra-226 alarm
EMS-518<>4-7-2004
30904<>10-31-2003
MCA124
MCA291
EMS 004
Am241#535-2-3;Cs137#535-3-1;Co60#535-3-3
Dale Seiller/12345
NA
NA
```

5.2 EMS Field Setup

The EMS is more complex than other real time systems designed for the FCP by the INEEL. Whereas RTRAK, RSS and Gator can be operated independently of the FCP control van, the EMS requires the van computer for command and control of the EMS hardware.

5.2.1 Dart Setup and Initialization of the MCB/Detector System

When power is applied to the EMS, all systems become operable automatically. However the Dart multi-channel buffer (MCB) does not automatically apply high voltage to the detector upon boot-up. This must be done manually, outside of the EMS software suite. Since the EMS computer, which controls the detector and MCA does not normally have a CRT or keyboard attached to it, the detector high voltage must be set remotely from the control van computer. To do this, the EMS and control van computers must be running and communicating with each other through their wireless network. When this is the case, the control van computer, working through the EMS computer, can set operating parameters for the Dart MCA and gamma ray detector by running the GammaVision® software provided by ORTEC. GammaVision® is the standard software package used by the FCP to acquire spectral data in a standalone fashion. This software is capable of communicating with and controlling ORTEC detector hardware over a standard computer network. Control of an MCA at a remote location by GammaVision® is transparent to the van computer operator and is similar to adjusting a Dart MCA that is linked directly by cable to the computer.

After the detector high voltage has been set, data acquisition can be initiated by running **ems.exe**, as described in the following section.

5.3 EMS Software Menu System

The EMS software suite resides on three separate computers: the control van computer, the EMS computer on the excavator arm and the computer in the excavator cab. Four separate software executables make up the EMS software suite: **ems_3-0.exe, ems_van_3-1.exe, CAB_3-0.exe** and **Egas.exe**. The executable file **ems_3-0.exe** interacts directly with all of the instruments that collect and analyze data and provide collision warning alarms. However, because **ems_3-0.exe** is run on the EMS computer which is located on the excavator arm and which has no keyboard or monitor, all analyst

interaction with this executable must take place through the **ems_van_3-1.exe** executable, which resides on the control van computer. **CAB_3-0.exe** is run on the cab computer. This executable collects and displays information that is useful for the excavator operator, such as current detector position, scan area coverage and collision warning alarms. The cab software furnishes information that helps to avoid damaging the instrumentation; but it is not critical to the analytical function of the EMS. There is no feedback from the cab display to either the EMS or the control van computer. The excavator cab software can be turned off from the control van if desired. The following subsections describe the operation of each of these software executables. The executable **Egas.exe** is run when the EMS is used to acquire HPGe data in a point and shoot mode. It is not used to collect NaI data in a mobile scanning mode.

5.3.1 Control Van Software Operation

The control van represents the main point of interface between the real time analyst and the entire EMS software suite. It is similar in style to the FCP NaI software system used by the RTRAK, RSS and Gator platforms. As shown in Figure 5-2, immediately after starting the EMS van software, the analyst is prompted to choose the type of detector that will be used. Making this choice will establish an expected mode of operation for the EMS (stationary or mobile scan) and select various default parameter values on the electronic worksheet. For example, if an HPGe detector is selected, the software defaults to the Point/Look mode. The operator can manually override these default selections, if desired, as described in the following text.

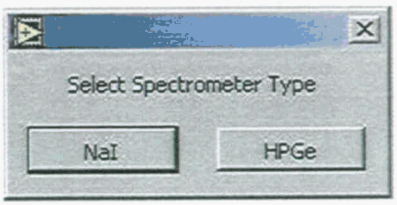

Figure 5-2. EMS select spectrometer type prompt

After making this choice, the main screen of the EMS control van software (Figure 5-3) will be displayed. The EMS has a number of control buttons that accomplish additional system configuration. The **NaI or HPGe** button is designed primarily as a status button, but can be manually used to change the selected spectrometer type if desired. In general, this should be avoided. The EMS can be used in either a scanning or a point and look mode. This selection is made using the **Scan or Point/Look** button. The **Energy Calibration Spectrum Summation** button specifies the number of spectra used in the automated gain tracking energy calibration calculation. This control is relevant only to sodium iodide detectors, and is ignored when the EMS is operated in the stationary point and shoot (HPGe) mode. The **Extensions** button provides a pull-down menu used to select the length of the extensions between the EMS main frame and the spectrometer. If *in situ* measurements are needed in abnormally deep excavations, extension rods must be manually added to the EMS mast, just above the detector, to insure that the excavator can reach to the bottom of the excavation. The **Exit VAN OS** button is used to completely shut down the EMS operating system and computer. The **CAB Network** button turns on the excavator cab display so that the heavy equipment operator can view continuously updated information. The **Bring EMS OS Down** button is used to shut down the EMS (excavator arm) software while leaving the Windows operating system running. This option is normally used to transfer files between the EMS Van and EMS excavator arm computers using the file sharing capabilities of the Windows operating system.

There are six system-status indicators used to convey information to the analyst in the control van. The **MCB Fail** and **DET Fail** lights indicate the condition of the gamma spectrometry hardware on the EMS excavator arm. The High Voltage indicator displays the actual value of the high voltage setting on

the detector. The **TCP Write Error, Net Read Fail**, and **EMS Heartbeat** lights show the condition of the wireless network link between the van computer and the EMS excavator arm computer.

The **PRESS HERE TO START DATA ACQUISITION** button should be pressed once the desired operating parameters have been selected, and the operator is satisfied with the status of the EMS system. This will bring up a sequence of display panels associated with the electronic worksheet that are nearly identical to the NaI operating software described in Section 3 of this manual.

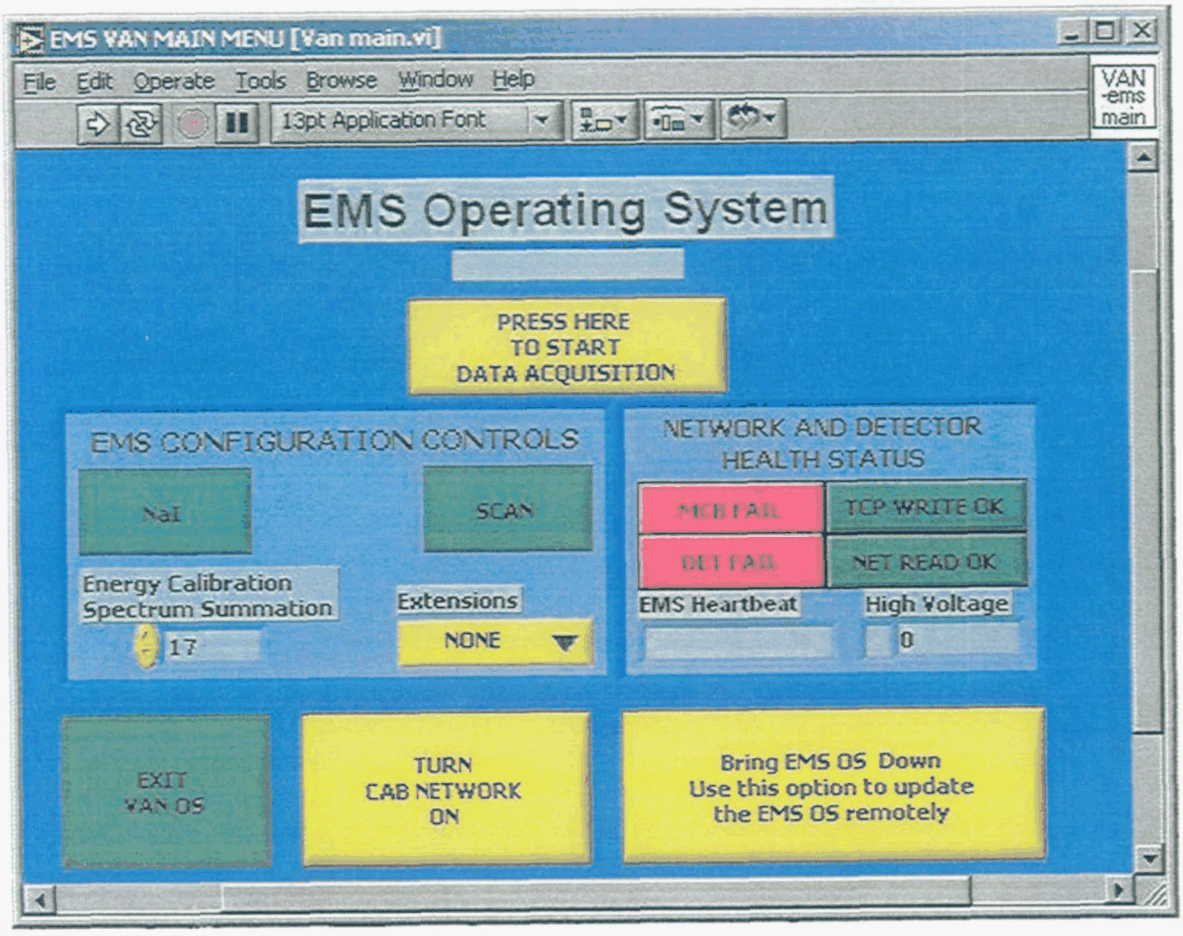

Figure 5-3. EMS control van main menu display

The EMS software will ask the operator to create a new electronic worksheet or select an existing one as shown in Figure 3-2. The electronic worksheet for the EMS system will be placed in either the c:\emsdata or the c:\hpgedata folder in a subfolder that corresponds with the date of the data acquisition. The data collected by the EMS are organized by date and batch number in a fashion identical to the NaI software system described in Section 3. Figures 3-3 through 3-7 located in Section 3 of this manual describe the operation of the electronic worksheet. Pressing the **SAVE AND EXIT** button on the electronic worksheet saves it to disk and presents the main EMS data acquisition screen (Figure 5-4) to the operator.

The EMS panel of the tab control structure contains a large X-Y display that shows the location and activity of analyzed spectra. Activity for total uranium, Ra-226, Th-232 and CPS can be shown by pressing the activity buttons that are located to the right of the X-Y display. The **START SCAN** and **PAUSE SCAN** button can be used to start and stop data acquisition. Other indicators on the EMS tab are the spectrum file name located directly above the X-Y activity chart, a spectrometer **IDLE** or **ACTIVE**

indicator, the location of the 2614 keV calibration peak in terms of MCA channel number, the percentage dead time (**%Dead Time**) of the spectrum, the true and live times of the spectrum, and ultrasonic sensor standoffs in terms of feet to the nearest object. Near the bottom right-hand corner of the panel there are several GPS related indicators including the current PDOP value, whether the GPS is being received and if it is differentially corrected, and the sweep speed of the EMS detector. Between the GPS indicators and the X-Y chart are several warning indicators. The **Dead Time** warning button turns red when the dead time exceeds 20%. The **Sum E-Cal** warning button turns red when the energy calibration peaks drift more than 15 channels from their nominal locations in the spectrum. The **Ind E-Cal** button turns red when a single spectrum fails energy calibration criteria. This will occur with some regularity and is not normally an indication of a serious equipment problem. The **CPS**, **Total U**, **Ra-226**, and **Th-232** warning buttons turn red when activity values exceed the upper limits established in the EMS configuration file (see Table 5-1).

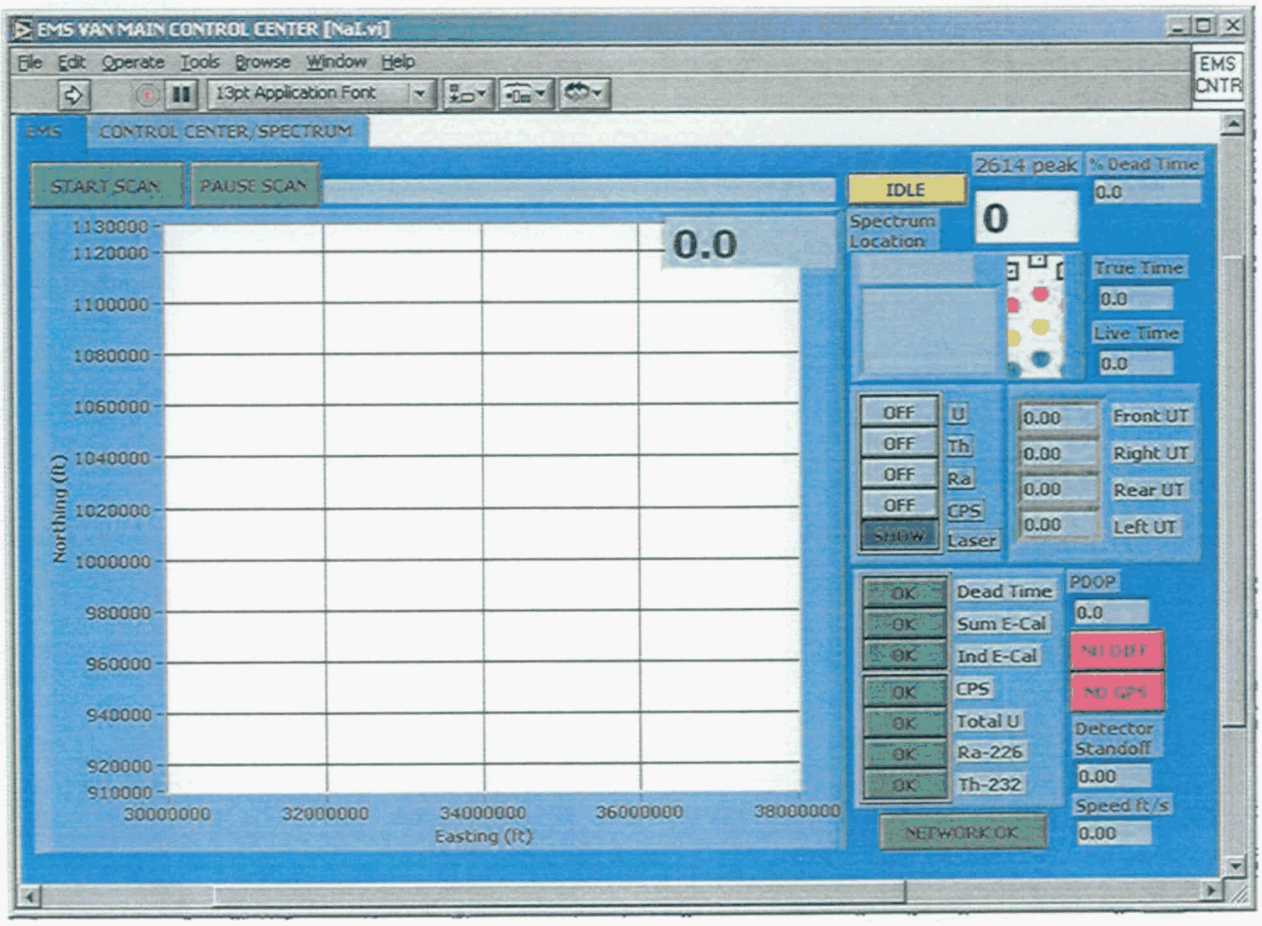

Figure 5-4. EMS main control center and operations panel (NaI mode)

The EMS tab control looks slightly different when operating in HPGe mode. The HPGe screen is shown in Figure 5-5. The major differences are that the **START SCAN** and **PAUSE SCAN** buttons have been removed and replaced with a pop-up prompt to begin acquisitions of a single spectrum. The **2614 Peak** location indicator has been replaced with the resolution (in terms of MCA channels, rather than energy) of the K-40 peak as determined by the EGAS analysis engine. Also, the activities of total uranium, K-40, U-238, Th-232, and laboratory corrected Ra-226, as determined by the EGAS analysis engine, are displayed in a pop-up window located over the upper left-hand corner of the X-Y areal display chart.

The EMS software runs a subset of the EGAS code, **Egas.exe**, to analyze gamma ray spectra collected with an HPGe detector. In most cases, this is transparent to the analyst. However, occasionally this simplified version of EGAS will be unable to process a spectrum automatically. In such rare cases, the analyst is notified that EGAS experienced a run-time problem as shown in Figure 5-6. The operator will need to analyze the spectrum manually using the full EGAS code.

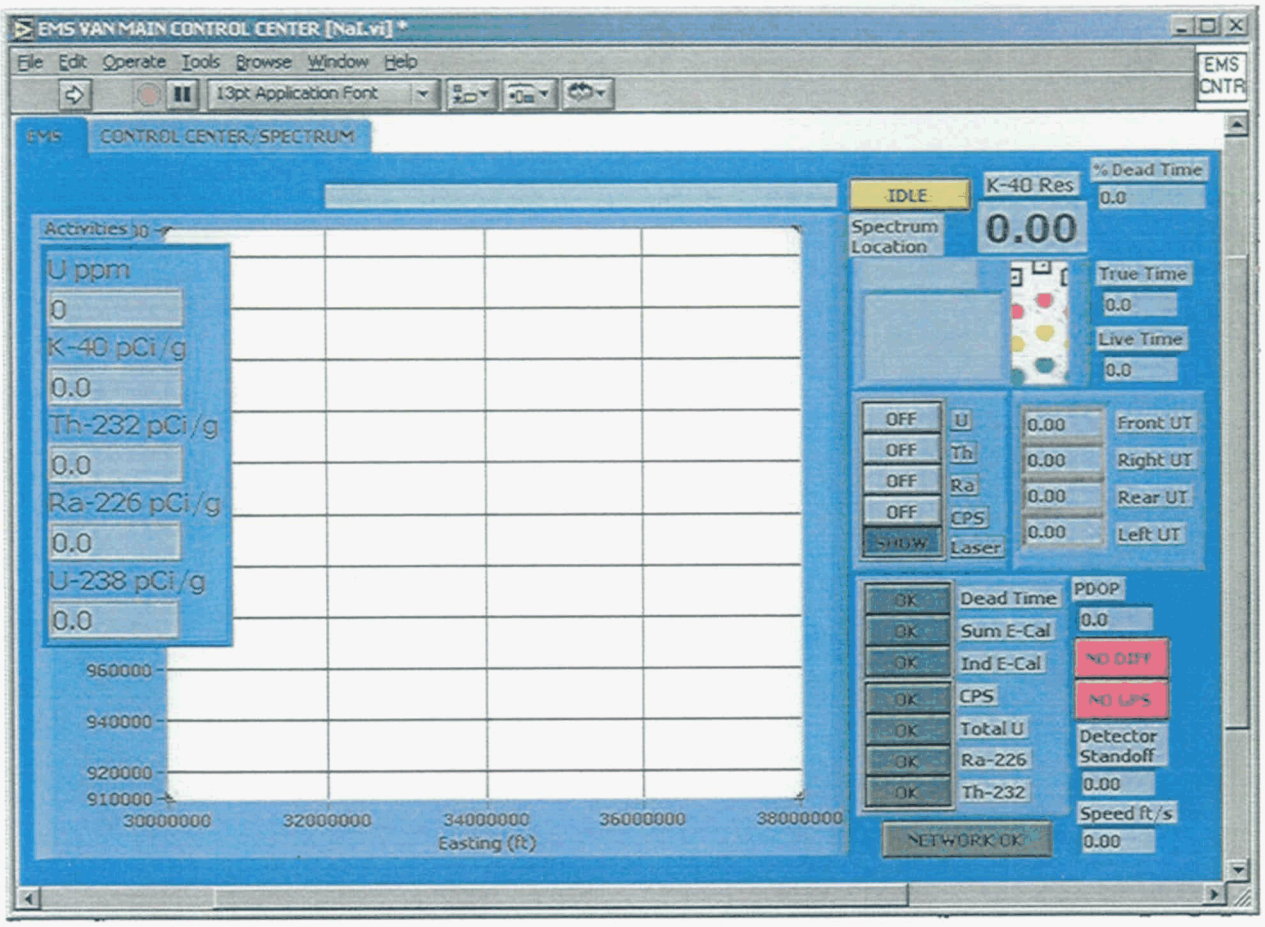

Figure 5-5. EMS control center and operations tab (HPGe mode)

Figure 5-6. EMS software indicating an EGAS run error

The **CONTROL CENTER/SPECTRUM** tab of the EMS control van main data acquisition screen has both controls and indicators located in various areas of the panel as shown in Figure 5-7. Located in the **CONTROL CENTER** box in the upper left portion of the screen are controls to change the spectral acquisition preset live or true time. Spectrometer presets are based on real time for scanning (NaI) operations and on live time for point and look (HPGe) operations. The preset "true time" (or real time) of the spectrometer can be changed at the beginning of each scan sequence, with multiple scan sequences

being allowed. The preset "live" time can be changed prior to a start of a single spectrum acquisition. Above these preset controls are indicators for the detector name and whether the EMS is operating in Scan or Point/Look mode. The **HPGE Abort** button is active during HPGe operations and can be used to manually stop an acquisition if desired. Located on the right-hand side of the screen for this tab are controls for the ArcSecond positioning system. These controls have been disabled for Version 3.1 of this software because this positioning system was rarely used. However, the software and controls have been preserved in the event that this system is reactivated. Controls located near the top-middle part of the panel include the **CLEAR** chart button and the **Draw Scaled Coverage** button. These buttons function similarly to their counterparts in the NaI software described in Section 3 of this manual. Below these buttons are indicators for detector position in terms of easting (E), northing (N), and altitude (Alt). Finally, the raw spectrum collected by the system is shown across the bottom portion of the control center tab panel.

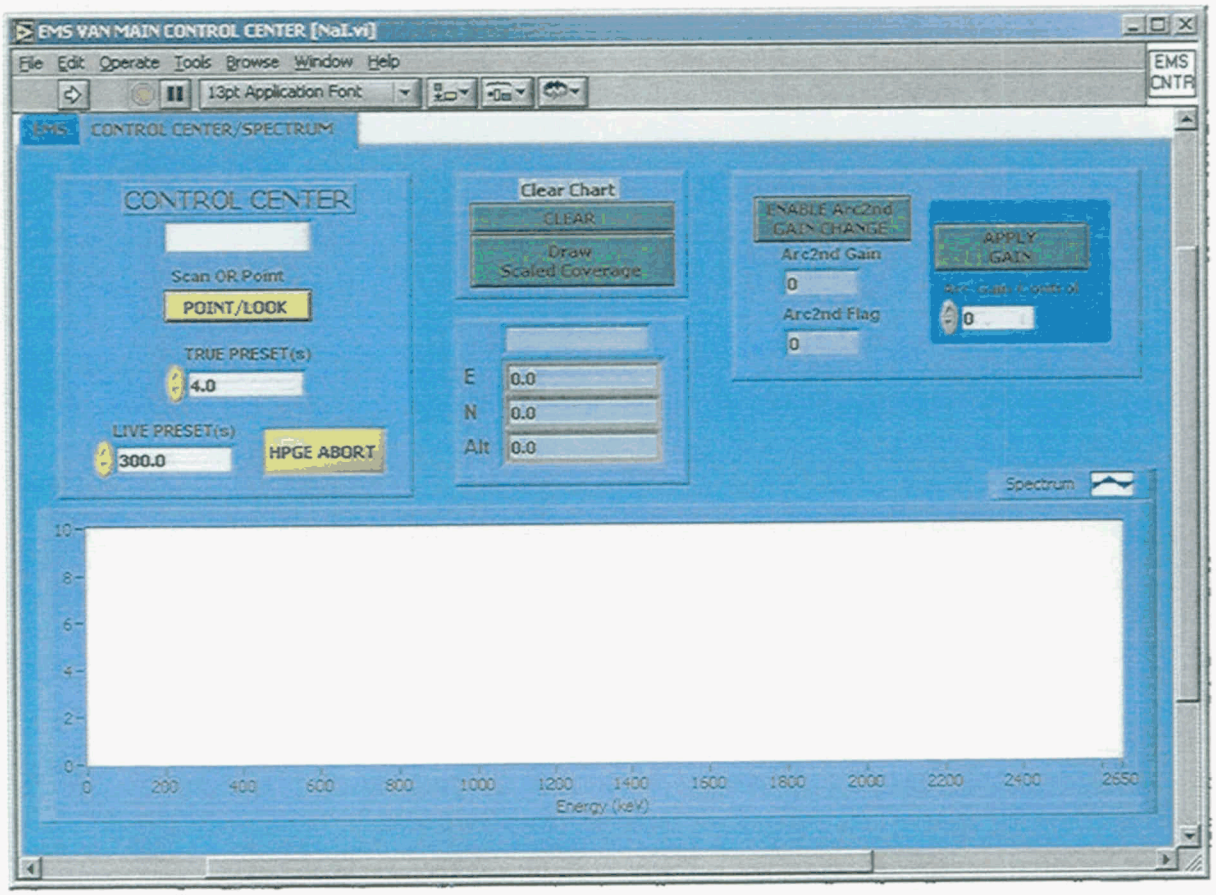

Figure 5-7. EMS main display Control Center/Spectrum tab

After the spectrometer has timed upon completion of a single shot HPGe acquisition, or after the operator has pushed the **END SCAN** button, the operator will be asked if another SCAN or a point/shoot spectrum is required as shown in Figure 5-8.

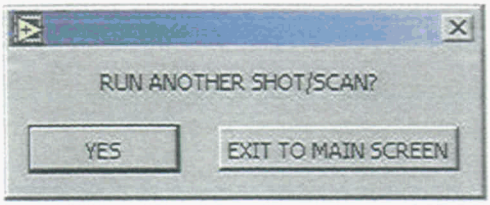

Figure 5-8. Acquire another spectrum prompt at the end of a scan or single HPGe shot

5.3.2 Draw Coverage Button

If the user presses the Draw Scaled Coverage button, a scaled coverage plot appears on the screen similar to that shown in Figure 3-11. The axes and grid lines of the scaled coverage plot are labeled with northing and easting coordinate values (in Ohio State Plane South coordinates). Horizontal and vertical grid lines are shown at intervals of 50 feet. The coverage plot draws a blackened area over every spectral data point collected. Sodium iodide spectral coverage areas are drawn based on the field of view of the gamma detector and the velocity of the EMS. The individual rectangles, which represent the coverage area of a single spectral measurement, are oriented along a vector between consecutive data points. Therefore, the coverage squares are aligned with the travel path of the detector, giving a true representation of the ground area scanned by the NaI detector. Since HPGe detectors are stationary during data acquisition, the HPGe detector coverage area is the same as the detector field of view, which is a function of height of the detector above the ground. HPGe measurement coverage areas are represented as circular areas on the coverage plots. Along the bottom of the panel are the "PRINT & EXIT" and "EXIT" buttons. The "PRINT & EXIT" button should only be used if a printer is attached to the data acquisition computer.

5.3.3 Excavator Cab Software

The EMS excavator cab software is a stand-alone executable that resides on an industrial computer located in the excavator cab. The cab computer is networked to the EMS computer through a wireless radio frequency Ethernet connection. This software gives the cab operator an overhead display that shows current location and the coverage track. It is also capable of providing a scaled coverage plot similar to that available in the EMS van. This display enables the excavator operator to determine when 100% coverage of a scan area has been achieved. The overhead display incorporates touch-screen technology to simulate the presence of a mouse.

The front panel of the EMS Excavator Cab software is shown in Figure 5-9. The front panel contains three controls and ten indicators. The large X-Y chart indicator (**Spectrum Location**) is similar to X-Y chart in the control van (Figure 5-4) in that it provides position information in world coordinates displayed as a function of distance from the ground surface. A digital indicator of current position is located in the lower left portion of the EMS Excavator Cab panel. Four ultrasonic sensors mounted on the EMS excavator tool, and pointing in four perpendicular directions, measure the horizontal distance to nearby objects or surfaces such as trench walls. They serve as proximity alarms that warn the excavator operator if the detector is about to strike an object. On-screen indicators for these sensors are located above, below, and to the sides of the large X-Y Spectrum Location chart (**Forward Ult Sensor**, **Right Ult Sensor**, **Rear Ult Sensor**, and **Left Ult Sensor**). Normally the background color of these indicators is green, but they will turn red when the measured distance from the tool to a nearby object or surface is less than some pre-set value, usually 1.25 feet. The **Detector Center to Ground (ft)** indicator is located on the upper left-hand corner of the Excavator Cab panel. This indicator displays the distance from the bottom of the detector to the ground surface to help avoid striking the ground with the detector. Associated with this indicator, below it, there is an alarm indicator, which turns red when the detector-to-ground distance falls below a pre-set value (1.0 foot in Figure 5-9). In the upper right-hand corner of the panel is the **Speed (ft/s)** indicator. This displays the ground speed of the tool/detector. The final

indicator is the **Network OK?** Indicator to the left of the large X-Y chart. It is normally green indicating a healthy network connection to the EMS computer.

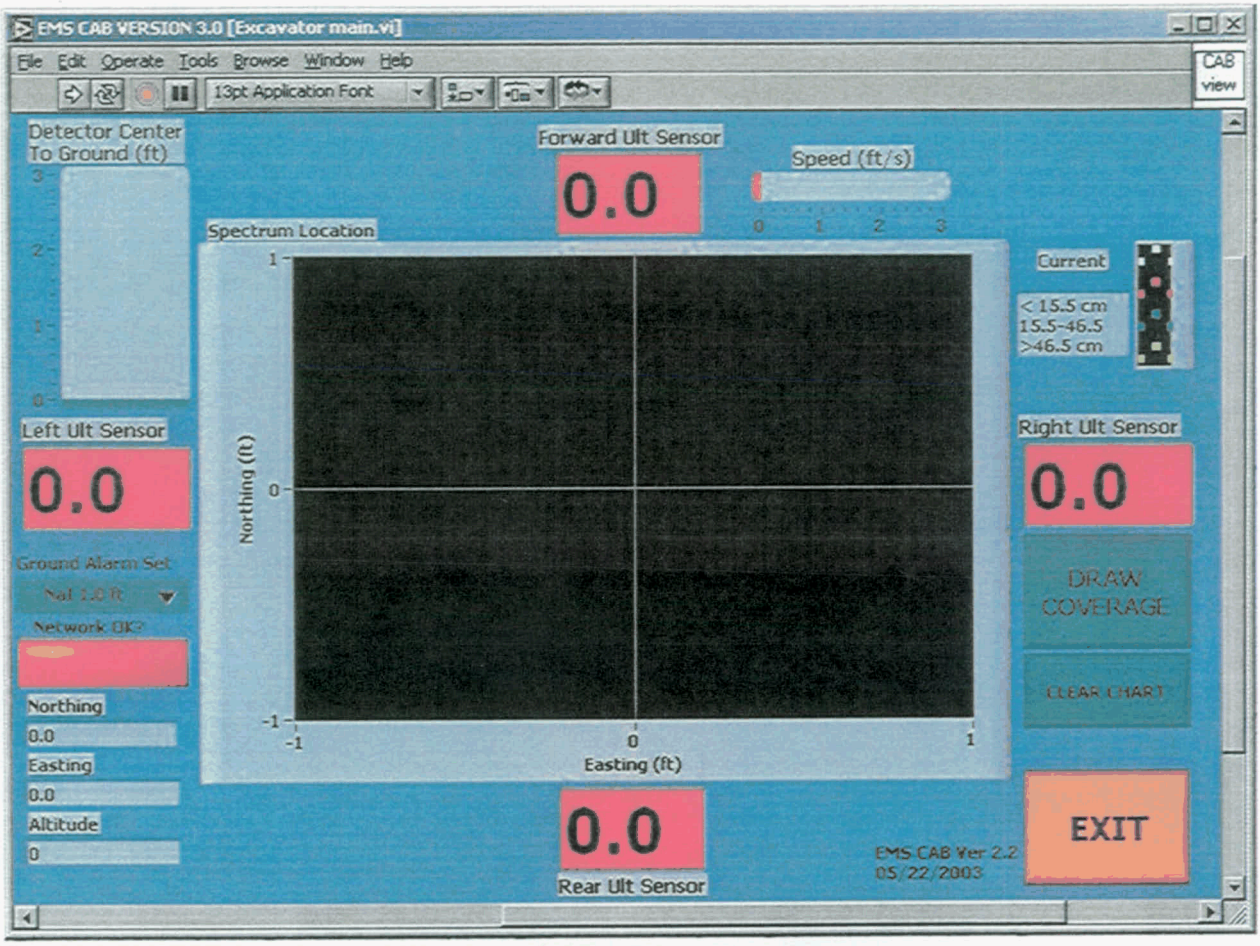

Figure 5-9. Excavator cab operator display

Three controls appear on the front panel of the excavator cab software display. These are the **EXIT**, **CLEAR CHART**, and the **DRAW COVERAGE** buttons. The Exit button simply terminates the excavator cab executable. The **CLEAR CHART** button clears the circular buffer used to generate the **Spectrum Location** X-Y graph. This can be useful if the operator wants to view recent data, which is being cluttered by large amounts of older data. The **DRAW COVERAGE** button opens a front panel similar to that available from the control van (see Figure 3-11). This provides a scaled coverage plot of the data in the circular buffer.

6.0 OUTPUT FILES AND FORMATS

The FCP Version 3.1 real time software suite generates a number of output files. There are some differences between the sodium iodide and germanium output files. However, the electronic worksheet, which is used to document measurement conditions, operational parameters and other relevant information, is the same regardless of whether NaI or HPGe software is being run. The electronic worksheet is described in the next subsection of this chapter, and, following that, the NaI and HPGe output files are described.

6.1 Universal Electronic Worksheet

The universal worksheet VI creates a text file that can be viewed by any text editor such as Notepad. The text file format follows closely the display format (see Figures 3-3 and 3-6), and is provided in Table 6-1. Lines one through sixteen contain the information found on the upper part of the worksheet display. Each line in Table 6-1 consists of a short field descriptor, followed by a colon, and then the actual data. Line one contains the version number and build date of the real time software used to generate the electronic worksheet and the log file. Line seventeen contains the number of "batch entries" on the worksheet. In the example in Table 6-1, there is only one batch. The next record(s) contain data pertinent to each batch. Batch data entries are separated by the "||" character sequence and are in the following order: project name, project number, location, batch number, background radiation level, detector height, run time, moisture percentage, start time, stop time, number of spectra collected, and comments. This information is repeated for every batch record. Data from the detector pre-operational check follows the batch data and consists of three records with four entries per record. Once again, data entries within a single record are separated by the "||" character sequence. The record entries are QC peak energy, peak channel number, resolution, and net peak area. Entries for HPGe detectors will have pre-operational QC data values in all three records. However, the third record for pre-operational NaI checks is not used (all four entries are 0.0). Post-operational instrument performance check results, displayed in the same format, follow the pre-operational data.

Table 6-1. Universal worksheet electronic worksheet text format

Line	Universal Worksheet
1	Version: Ver 2.0 10/11/2002
2	Date: Sep-30-2002
3	1st: Jerry Smith
4	2nd: Dale Seiller
5	3rd: John Doe
6	Det: RTRAK-526
7	MCA: Digi Dart 123
8	u-r: Meter 456
9	Det Cal: 03-21-2002
10	Meter Cal: 01-04-2003
11	Weather: clear
12	Temp: 68
13	Humid: 40
14	Review By:
15	Review Date:
16	Check Source: Am241#535-2-3;Cs137#535-3-1;Co60#535-3-5
17	1
18	proj_name || Proj_number || Location || 0001 || 1.2 || 31 || 4.00 || 30.0 || 13:47:46 || 13:50:10 || 0 || comments
19	Pre Op
20	238.0 || 40.0 || 0.00 || 1000
21	2614.0 || 447.0 || 0.00 || 2000
22	0.0 || 0.0 || 0.00 || 0
23	Post Op
24	238.0 || 40.0 || 0.00 || 1000
25	2614.0 || 447.0 || 0.00 || 2000
26	0.0 || 0.0 || 0.00 || 0

6.2 Sodium Iodide Output Files

The NaI software stores each spectrum collected using the industry standard ORTEC integer data file (.CHN) format. This file format is described completely in the ORTEC Software File Structure Manual.[5] Each spectrum is written to disc with the calculated energy calibration and acquisition specific information written in the sample description field of the CHN file. The sample description field contains the northing, easting, altitude, detector height, PDOP, the GPS quality indicator and soil moisture values obtained from the electronic worksheet entries. An example sample description is provided in Table 6-2.

Table 6-2. Example sample description header of a typical spectral file

479292.1, 13487714, 581.6, 31 cm, D: 4.6, G: 0, M: 0.22

All NaI systems at Fernald, including the EMS when a NaI detector is attached, generate log files having the same format. The log file contains a listing of the isotopic measurement results, GPS data, soil moisture, and a variety of error flags and other data quality indicators pertinent to each spectral measurement in the NaI batch. Each particular type of information is written into a designated column in the log file, as shown in Table 6-3. In addition to listing the type of information stored in each column, for data quality indicators, Table 6-3 also displays possible values for these indicators and the meaning of each value. The table also specifies whether the data in a given column are integer or real numbers. A

reviewer who scans down a single column in the log file can see how a particular parameter varied from one spectrum to the next, throughout the batch. Columns R, S, T, and U, ultrasonic proximity alarm sensor readings, are used only for the EMS with an attached NaI detector. Column BA contains the version number and the build date of the NaI executable used to generate the log file. Column BB contains the QA codes used to fill in the sodium iodide data verification checklist, which documents the review of NaI data before results are released to a customer.

Table 6-3. Version 3.1 NaI log file format

Column Number	Value	Error Description
A		GPS Error Flag: Integer.
	0	Good differential and GPS fix.
	1	Good GPS fix but no differential correction.
	2	No GPS fix.
	10	GPS timeout, but last data point OK
	11	GPS timeout, last data point no differential correction
	12	GPS timeout, last data point no GPS fix
B		GPS Precision Dilution of Position (PDOP): real.
C		Alarm Error Flag: integer.
	0	No alarms.
	1	Total CPS exceeds user definable alarm level.
	2	Total U exceeds WAC trigger.
	3	Total U exceeds WAC trigger and CPS exceeds alarm level.
	4	Ra-226 exceeds 3*FRL.
	5	Ra-226 exceeds 3*FRL and total CPS exceeds alarm level.
	6	Ra-226 exceeds 3*FRL and total U exceeds WAC trigger.
	7	Ra-226 exceeds 3*FRL, total U exceeds WAC trigger and total CPS exceeds alarm level.
	8	Th-232 exceeds 3*FRL.
	9	Th-232 exceeds 3*FRL and total CPS exceeds alarm level.
	10	Th-232 exceeds 3*FRL and total U exceeds WAC trigger.
	11	Th-232 exceeds 3*FRL, total U exceeds WAC trigger and total CPS exceeds alarm level.
	12	Th-232 and Ra-226 exceed 3*FRL.
	13	Th-232 and Ra-226 exceed 3*FRL, total CPS exceeds alarm level.
	14	Th-232 and Ra-226 exceed 3*FRL, and total U exceeds alarm level.
	15	Th-232 and Ra-226 exceed 3*FRL, total U exceeds WAC trigger and total CPS exceeds alarm level.
D	*x	Interference error string. A six-character string preceded by an asterisk. Each numeric byte represents an error described below.
	1st byte	0 if OK, 1 if more than 20% dead time.
	2nd byte	0 if OK, 1 if summed spectra energy calibration fails test criterion.
	3rd byte	0 if OK, 1 if single spectrum energy calibration fails test criterion.
	4th byte	0 if OK, 1 if summed spectra energy calibration fails at the 1460 keV peak.
	5th byte	0 if OK, 1 if summed spectra energy calibration fails at the 2614 keV peak.
	6th byte	0 if OK, 1 if single spectrum energy calibration fails at the 1460 keV peak.
E		Complete path and file name of spectrum. string
F		Date in ORTEC format (DDMMMYY*). string
G		Time in HH:MM:SS format. string
H		Detector description. string
I		Detector live time in seconds. real
J		Detector true time in seconds. real
K		Soil moisture content (decimal). real
L		Spectrum total counts. integer
M		Spectrum total counts per second. integer

Table 6-3. Version 3.1 NaI log file format

Column Number	Value	Error Description
N		Y coordinate or Northing in Ohio state plane system. real
O		X coordinate or Easting in Ohio state plane system. real
P		Z coordinate or elevation in Ohio state plane system. real
Q		Detector standoff in feet. real
R		Ultrasonic sensor #1 standoff in feet (not used in the NaI system). real
S		Ultrasonic sensor #2 standoff in feet (not used in the NaI system). real
T		Ultrasonic sensor #3 standoff in feet (not used in the NaI system). real
U		Ultrasonic sensor #4 standoff in feet (not used in the NaI system). real
V		U-238 signal window counts. integer
W		U-238 net (normalized) background counts. real
X		U-238 net CPS. real
Y		K-40 signal window counts. integer
Z		K-40 net (normalized) background counts.
AA		K-40 net CPS.
AB		Th-232 signal window counts.
AC		Th-232 net (normalized) background counts.
AD		Th-232 net CPS.
AE		Ra-226 signal window counts.
AF		Ra-226 net (normalized) background counts.
AG		Ra-226 net CPS.
AH		Moisture corrected total Uranium in ppm.
AI		Moisture corrected K-40 activity in pCi/g.
AJ		Moisture corrected Th-232 activity in pCi/g.
AK		Moisture and lab Radium corrected Ra-226 activity in pCi/g.
AL		Moisture corrected U-238 activity in pCi/g.
AM		Moisture corrected total U MDC in ppm.
AN		Moisture corrected K-40 MDC in pCi/g.
AO		Moisture corrected Th-232 MDC in pCi/g.
AP		Moisture and lab Radium corrected Ra-226 MDC in pCi/g.
AQ		Moisture corrected U-238 MDC in pCi/g.
AR		Moisture corrected 95% uncertainty total Uranium (ppm)
AS		Moisture corrected 95% uncertainty K-40 (pCi/g)
AT		Moisture corrected 95% uncertainty Th-232 (pCi/g)
AU		Moisture corrected 95% uncertainty Ra-226 (pCi/g)
AV		Moisture corrected 95% uncertainty U-238 (pCi/g)
AW		Energy calibration zero offset for summed spectra
AX		Energy calibration slope for summed spectra
AY		Energy calibration zero offset for single spectrum
AZ		Energy calibration slope for single spectrum
BA		Software version number and build date

Table 6-3. Version 3.1 NaI log file format

Column Number	Value	Error Description
BB	*xxxxxxxx	QA codes string. An eight-character string preceded by an asterisk. Each numeric byte represents an error described below.
	1st byte	Overall sample, 0 = OK, 1 = reject, 2 = sample suspect
	2nd byte	Radon correction, 0 = uncorrected, 1 = lab only, 2 = lab and diurnal correction.
	3rd byte	Not used for NaI
	4th byte	Not used for NaI
	5th byte	Not used for NaI
	6th byte	Not used for NaI
	7th byte	Not used for NaI
	8th byte	Not used for NaI

6.2.1 NaI Temporary Scratch Files

The real time NaI software, including the NaI portion of the EMS executable, creates two temporary scratch files during normal execution of the software. These files are normally deleted automatically by the software, but may remain if the software aborts or is aborted in an abnormal manner. The NaI software, using a GammaVision job file, generates ROI report files for pre- and post-operational instrument performance checks. The universal electronic worksheet editor code extracts peak resolution and net peak area information from the ROI report files for instrument performance checks. The job file itself is a file that is continuously written over and called by the NaI software. An example NaI job file is shown in Table 6-4. An example ROI report file is shown in Table 6-5. Temporary ROI report files will always be located in the *c:\FEMP\GV* folder.

Table 6-4. Example NaI job file used to generate a GammaVision ROI report file

```
SET_BUFFER
RECALL "D:\Fernald\data\EMS 169\0170.Chn"
RECALL_ROI "C:\FEMP\GV\NaIQC_V2.0.ROI"
REPORT "C:\FEMP\GV\nai_rpt.rpt"
WAIT 1
QUIT
```

Table 6-5. Example ROI report file used for net peak area calculation

```
Detector #1     ACQ 02-Jun-2003 at 15:36:11   RT = 126.5   LT = 120.0
        22UC3 MCB 9 DART
        EMS,Postop,#0170

ROI # 1     RANGE: 37 = 217.92keV  to  50 = 294.11keV
        AREA : Gross =  68623    Net = 18193   +/- 292
        CENTROID: 43.60  = 256.63keV
        SHAPE: FWHM = 32.72     FW(1/5)M = 45.02
        No close library match.

ROI # 2     RANGE: 420 = 2462.62keV  to  474 = 2779.10keV
        AREA : Gross =  7854    Net = 6076   +/- 143
        CENTROID: 445.09  = 2609.67keV
        SHAPE: FWHM = 122.05     FW(1/5)M = 187.78
        No close library match.

ROI # 1     RANGE: 37 = 217.92keV  to  50 = 294.11keV
        AREA : Gross =  68623    Net = 18193   +/- 292
        CENTROID: 43.60  = 256.63keV
        SHAPE: FWHM = 32.72     FW(1/5)M = 45.02
        No close library match.

ROI # 2     RANGE: 420 = 2462.62keV  to  474 = 2779.10keV
        AREA : Gross =  7854    Net = 6076   +/- 143
        CENTROID: 445.09  = 2609.67keV
        SHAPE: FWHM = 122.05     FW(1/5)M = 187.78
        No close library match.
```

6.3 HPGe Output Files

The HPGe software systems store each spectrum collected using the industry standard ORTEC integer data file (.CHN) format. HPGe data files have the same format as NaI files, except that they contain 8192 channels of spectral data instead of 512 channels. This file format is described in detail in the ORTEC Software File Structure Manual (ORTEC). Each spectrum is written to disc with the calculated energy calibration and acquisition specific information written in the sample description field of the CHN file. The sample description field for an HPGe spectrum is different from that generated by the NaI software. It contains the HPGe detector ID, location ID, northing, easting, altitude, detector height, and soil moisture value obtained from electronic worksheet entries. An example sample description is provided in Table 6-6.

Table 6-6. Example HPGe sample description field

30699, Bldg45-PSP-238, 479292, 1348771, 582, 31cm, M:0.22

The HPGe summary file format is similar to the NaI log file format and is shown in Table 6-7.

Table 6-7. HPGe summary file format

Column Number	Value	Error Description
A	0 1 2	GPS Error Flag: Integer. Good differential and GPS fix. Good GPS fix but no differential correction. No GPS fix.
B		GPS Precision Dilution of Position (PDOP): real.
C		Ultrasonic sensor #1 standoff in feet (not used in HPGe system). real
D		Ultrasonic sensor #2 standoff in feet (not used in HPGe system). real
E		Ultrasonic sensor #3 standoff in feet (not used in HPGe system). real
F		Ultrasonic sensor #4 standoff in feet (not used in HPGe system). real
G		Spectrum file name.
H		Date in ORTEC format (DDMMMYY*). string
I		Time in HH:MM:SS format. string
J		Detector live time in seconds. real
K		Detector percentage dead time. real
L		Detector ID
M		Spectrum location ID
N		Y coordinate or Northing in Ohio state plane system. real
O		X coordinate or Easting in Ohio state plane system. real
P		Z coordinate or elevation in Ohio state plane system. real
Q		Detector height in cm. real
R		Soil Moisture (decimal). real
S		K-40 pCi/g
T		one-sigma K-40 % error
U		K-40 MDC pCi/g
V		U-238 pCi/g
W		one -sigma U-238 % error
X		U-238 MDC pCi/g
Y		Ra-226 pCi/g
Z		one -sigma Ra-226 % error
AA		Ra-226 MDC pCi/g
AB		U-235 pCi/g
AC		one -sigma U-235 % error
AD		U-235 MDC pCi/g
AE		Th-232 pCi/g
AF		one -sigma Th-232 % error
AG		Th-232 MDC pCi/g
AH		Th-230 pCi/g
AI		one -sigma Th-230 % error
AJ		Th-230 MDC pCi/g
AK		K-40 Resolution
AL		Total Uranium in ppm

Table 6-7. HPGe summary file format

AM		Software version number and build date
AN	*xxxxxxxx	Quality Assurance Codes. An eight-character string preceded by an asterisk. Each numeric byte represents an error described below.
	1st byte	0 = result OK, 1 = reject sample, 2 = flag sample as suspect.
	2nd byte	0 = uncorrected, 1 = Lab corrected only, 2 = Lab and radon corrected.
	3rd byte	0 = OK, 1 = reject U-238 results, 2 = suspect, 3 = cannot assess.
	4th byte	0 = OK, 1 = reject Ra-226 results, 2 = suspect, 3 = cannot assess.
	5th byte	0 = reserved for U-235.
	6th byte	0 = OK, 1 = reject Th-232 results, 2 = suspect, 3 = cannot assess.
	7th byte	0 = reserved for Th-230.
	8th byte	0 = n/a, 1 = consecutive duplicate, 2 = non-consecutive duplicate.
AO	*xxx	Duplicate Codes. A three-character string preceded by an asterisk. Each numeric byte represents an error described below.
	1st byte	0 = if all nuclides ≥ MDC are ≥ MDC in both spectra, 1 = MDC failure, 2 = not assessable.
	2nd byte	0 = for nuclides ≥ MDC but < 5*MDC, the difference is ≤ MDC, 1 = failure, 2 = not assessable.
	3rd byte	0 = For nuclides ≥ 5*MDC, the RPD is < 20% (35% for non-consecutive duplicates), 1 = failure, 2 = not assessable.

The real time HPGe software calls a simplified version of the EGAS spectral analysis package. This simplified EGAS generates a summary file and a report file. Isotopic analysis results are read from the EGAS summary file, they are reformatted, and written into the real time HPGe summary file (columns **S** through **AL**) shown in Table 6-7. In addition to listing isotopic analysis results, the real time software also performs some data quality checks based on preset limits for various measured quantities. The results of these data quality checks are listed as QA codes and Duplicate codes in columns **AN** and **AO**, respectively. One of the quality checks performed by the software is a comparison of isotopic results for U-238, Th-232 and Ra-226 from low energy gamma lines to the result based on a high energy gamma emission.

The EGAS report file from an individual spectrum analysis contains weighted mean activity results for isotopes listed in what is called the "cut list." It also contains activity calculations for each individual gamma-ray peak found in the spectrum. The EGAS report files for all the spectral analyses in a batch are merged together to form a master report file. An example of a portion of an EGAS report file is shown in Table 6-8. The interested reader is encouraged to review the EGAS operations manual for more detailed information concerning the technical details of the EGAS software package.

Table 6-8. Example upper portion of an HPGe report file

```
  3053.CHN     , 31265,A1P4-P2-8,480032,1350858,581,31cm,Moist:0.14

          **  EGAS Version: 050803/ 31265/Q by R. T. Reiman **

Energy  Resolution Live Time Real Time   Quad     Gain    OFFSET  HEIGHT
 (keV)  FWHM (keV)  Seconds   Seconds   Value   (kev/ch)  (keV)    (cm)
******* ********** ********* ********* ******** ******** ******** ******
 1460.8      2.21       300       310  .243E-07 .375     .902E-01     31


                              Nuclide Summary
                              ***************
                Isotope       Activity        Error      MDA
                            pCi/g    uCi/m2     %       pCi/g
                ******* ********* ********* ****** *********
                K-  40  25.3      .380E+06    2.1    1.71
                Ra 226  1.32      .199E+05    3.7    .160
                Th 232  1.45      .218E+05    4.2    .201

                Estimate of total U:  .000     PPM


ENERGY    NET  BACKGROUND ERROR ISOTOPE  PHOTO-      ACTIVITY        EXPOSURE
(keV)    COUNT    COUNT    (%)           PEAK   (pCi/g)   (uCi/m2)  (uR/Hr)
******  *******  ******* ****** ******* ******* ********* ********* *********
   32.0     91.9    856.1   46   BA 133    31.0   .71       .11E+05   .00
                                Am 243    31.1   .61E+03   .92E+07
                                CS 137    32.1   7.9       .12E+06
   74.7    196.8   3688.2   44   Am 243    74.7   .28       .42E+04   .86E-02
                                PB 212    74.8   1.9       .29E+05
                                U- 235    74.9   .18E+05   .28E+09
                                Px  82    75.0   .18       .28E+04
   77.3    351.0   3452.0   24   Lu 174    76.5   4.0       .59E+05   .16E-01
                                Pu 241    77.0   .13E+07   .20E+11
                                PB 212    77.1   1.8       .28E+05
                                Bi 209    77.1   .32       .48E+04
                                PU 239    77.6   .75E+05   .11E+10
   238.6   774.7   1150.3    7   Pb 212   238.6   1.2       .18E+05   .12
                                TL 232   238.6   1.2       .18E+05
```

6.3.1 HPGe Temporary Scratch Files

The real time HPGe software, including the HPGe portion of the EMS executable, creates several temporary scratch files during normal operation of the software. These are normally deleted automatically by the software, but may remain if the software aborts or is aborted in an abnormal manner. The real time HPGe software generates ROI report files for pre- and post-operational instrument performance checks using a GammaVision job file. The universal electronic worksheet editor code extracts peak resolution and net peak area information from the ROI report files for instrument performance checks. The job file itself is a file that is continuously written over and called by the HPGe software. An example HPGe job file is shown in Table 6-9. An example ROI report file is shown in Table 6-10. Temporary ROI report files will always be located in the **c:\FEMP\GV** folder.

Table 6-9. HPGe JOB file created by the HPGe software and used by GammaVision

```
RECALL "C:\hpgedata\04-02-03\2315.Chn"
RECALL_ROI "C:\FEMP\GV\HPGEWIDE.ROI"
REPORT "C:\FEMP\GV\hpge_rpt.rpt"
WAIT 1
QUIT
```

Table 6-10. Temporary HPGe ROI report file

```
Detector #1      ACQ 17-Mar-2003 at  7:37:03   RT = 138.2   LT = 120.0
            MCB 9
            31265,PreOpCk,#2308

ROI # 1     RANGE: 148 = 55.80keV  to  168 = 63.29keV
            AREA : Gross =  20389    Net = 14526   +/- 170
            CENTROID: 158.68  = 59.80keV
            SHAPE: FWHM = 1.06     FW(1/5)M = 1.68
            ID: W-187 at 59.72keV
            Corrected Rate = 0.00 +/- 0.00 Bq

ROI # 2     RANGE: 1750 = 656.34keV  to  1776 = 666.09keV
            AREA : Gross =  40363    Net = 39314   +/- 207
            CENTROID: 1764.55  = 661.79keV
            SHAPE: FWHM = 1.59     FW(1/5)M = 2.45
            ID: Cs-137 at 661.62keV
            Corrected Rate = 0.00 +/- 0.00 Bq

ROI # 3     RANGE: 3532 = 1324.71keV  to  3574 = 1340.47keV
            AREA : Gross =  13116    Net = 12822   +/- 120
            CENTROID: 3553.47  = 1332.77keV
            SHAPE: FWHM = 2.15     FW(1/5)M = 3.30
            ID: Co-60 at 1332.51keV
            Corrected Rate = 0.00 +/- 0.00 Bq

ROI # 4     RANGE: 3885 = 1457.16keV  to  3905 = 1464.66keV
            AREA : Gross =  164    Net = 129   +/- 14
            CENTROID: 3894.88  = 1460.87keV
            SHAPE: FWHM = 1.75     FW(1/5)M = 2.88
            ID: K-40 at 1460.75keV
            Corrected Rate = 0.00 +/- 0.00 Bq
```

The HPGe software calls a simplified version of the EGAS spectral analysis engine to process Germanium spectra, as they are collected in the field. The full-featured EGAS software is run in an interactive mode, where the user is required to answer questions regarding the detector configuration and spectral analysis parameters. The simplified version of EGAS is designed such that the only analysis options available are the detector ID, soil moisture, and the detector height. The simplified EGAS engine reads these options from an ASCII file input deck. The real time HPGe software creates the ACSII input file prior to calling the EGAS analysis engine. It is continuously written over as multiple spectra are analyzed. An example of the ASCII EGAS input file is provided in Table 6-11. The first three lines of the EGAS input file contain the names of the spectrum file, the EGAS report file and the EGAS summary

file, and the last three lines contain the soil moisture, detector height and detector ID, respectively. This file will always be placed in the *c:\FEMP\EGAS* folder.

Table 6-11. EGAS input file created by the HPGe software

```
C:\FEMP\31265\rev\3129.chn
C:\FEMP\31265\rev\3129.rpt
C:\FEMP\31265\rev\3129.sum
0.22
15
31265
```

7.0 ANALYSIS AND COMPUTATIONS

The NaI and HPGe real time software packages perform a variety of computations including the conversion of satellite GPS coordinates to Ohio State Plane coordinates, energy calibration of each spectrum, and computation of activities and measurement uncertainties for each peak in each spectrum. These computations are described in this section.

7.1 Coordinate Systems

Both NaI and HPGe real time software packages communicate with the GPS units to acquire current position information directly from the satellite GPS receiver. The GPS receiver must be programmed to provide the NMEA ASCII text output to the computer running the real time software. The NaI and HPGe software can both use the $GPVTG, $PTNL, GGK and the $GPGGA strings from the satellite receiver. The $GPVTG string provides ground speed while the GGK and GGA strings provide position. The GGK string is used where real-time differential correction is available and the GGA string is used where differential correction information is not available.

The $GPVTG has eight data fields (including the track specifiers) and a checksum field as shown in Table 7-1. Only the NaI software uses the ground speed from the GPVTG string.

Table 7-1. $GPVTG transmission string format

Field	Description
$GPVTG	Beginning of a VTG transmission
x.x	Track, degrees true
T	Track trailer
x.x	Track, degrees magnetic
M	Magnetic track trailer
x.x	Ground speed in knots
N	Knots ground speed trailer
x.x	Ground speed in Km/hr
K	Km/hr ground speed trailer
*hh	Hexadecimal checksum

The $PTNL,GGK string furnishes GPS time, latitude, longitude, altitude, DOP, and GPS quality information to the NaI and HPGe codes. The NMEA format string has 11 data fields including unit specifiers as shown in Table 7-2.

Table 7-2. $PTNL, GGK transmission string format

Field	Description
$PTNL, GGK	Beginning of a PTNL, GGK transmission
x.x	Universal time clock (UTC) of position fix
d	Date in mmddyy format (101300 = October 13, 2000)
x.x	Geographic latitude in ddmm.mm format (degrees, minutes, decimal minutes)
N	Direction of latitude (N – North, S – South)
x.x	Geographic longitude in ddmm.mm format (degrees, minutes, decimal minutes)
W	Direction of longitude (W – West, E – East)
d	GPS quality indicator (0 – no fix, 1 – GPS fix, 4 – differential fix)
d	Number of satellites in use
x.x	Dilution of position (DOP)
EHTx.x	Antenna height above ellipsoid in meters.
M	Unit of ellipsoidal height (meters)

The $GPGGA string provides information regarding GPS time, latitude, longitude, altitude above mean sea level, GPS quality, and horizontal DOP to the real time software. The NMEA format has fourteen data fields as shown in Table 7-3.

Table 7-3. $GPGGA transmission string format

Field	Description
$GPGGA	Beginning of a GPGGA transmission
x.x	Universal time clock (UTC) of position fix
x.x	Geographic latitude in ddmm.mm format (degrees, minutes, decimal minutes)
N	Direction of latitude (N – North, S – South)
x.x	Geographic longitude in ddmm.mm format (degrees, minutes, decimal minutes)
W	Direction of longitude (W – West, E – East)
d	GPS quality indicator (0 – no fix, 1 – GPS fix, 2 – differential fix)
d	Number of satellites in use
x.x	Horizontal DOP
x.x	Antenna height above mean sea level reference
M	Unit of altitude (meters)
x.x	Geoidal separation
M	Unit of geoidal separation (meters)
x.x	Age of differential GPS data record
d	Base station ID

7.1.1 Conversion of Satellite Data to Ohio State Plane South Coordinates

The following information is paraphrased from the United States Geological Survey, Bulletin 1532 titled, "Map Projections Used by the U.S. Geological Survey" (Snyder 1984). This bulletin was initially published in 1982.

The NaI and HPGe software automatically converts latitude-longitude coordinates obtained from GPS satellites to Ohio State Plane South coordinates. The state plane coordinates used at the FCP facility are based on the NAD83 (or GRS80) ellipsoid. Therefore, all conversions stated herein are referenced to this ellipsoid. Table 7-4 defines parameters used in coordinate conversions.

Table 7-4. Parameter definitions used in coordinate conversion to Ohio State Plane South

a	=	Equatorial radius or semi-major axis of the reference ellipsoid
b	=	Polar radius or semi-minor axis of the reference ellipsoid
e	=	Eccentricity of the ellipsoid, $e = (1 - b^2/a^2)^{1/2}$
λ	=	longitude
ϕ	=	latitude
ϕ_1, ϕ_2	=	Standard parallels of latitude for the Lambert Conformal Conic projection.

The GRS80 ellipsoid constants used in the coordinate transformations for the equatorial and polar radii are shown in Table 7-5.

Table 7-5. GRS80 ellipsoid constants

a	=	6378137.0 meters
b	=	6356752.31414 meters

The Ohio State Plane South coordinate system uses a Lambert Conformal Conic projection to obtain rectangular grid coordinates. The longitude and latitude constants that comprise the standard parameters for the Ohio State Plane south coordinate system are shown in Table 7-6. Note that a west longitude, referenced from Greenwich, England is a negative sign.

Table 7-6. Ohio State Plane South constants

λ_0	=	Longitudinal origin, 82° 30′ west longitude (-82.5 degrees)
ϕ_0	=	Latitudinal origin, 38° north latitude (38.0 degrees)
ϕ_1	=	1st parallel, 38° 44′ north latitude (38.7333333 degrees
ϕ_2	=	2nd parallel, 40° 02′ north latitude (40.033333333 degrees)
FE	=	false easting, 600000.0 meters

There are three constants that can be computed prior to all subsequent latitude/longitude conversions. These constants vary according to the standard parameters of the Lambert Conformal Conic system in use (i.e., the constants in Table 7-6). These constants (n, ρ_0, and F) can be computed as shown in Table 7-7.

Table 7-7. Pre-computed constants used during the conversion process

n	=	$ln(m_1/m_2)/ln(t_1/t_2)$
F	=	$m_1/(n\ t_1^n)$
ρ_0	=	$a\ F\ t_0^n$

The parameters t_i and m_i can be computed as shown in Table 7-8.

Table 7-8. Intermediate parameters used in calculating constants

t_i	=	$tan(\pi/4 - \phi_i/2)/[(1 - e\ sin\phi_i)/(1 + e\ sin\phi_i)]^{e/2}$
m_i	=	$\cos\phi_i\ /(1 - e^2\ sin^2\phi_i)^{1/2}$

To obtain t_0, t_1, t_2, m_1, and m_2 insert the corresponding latitude (i.e., ϕ_0, ϕ_1, or ϕ_2) into the above equations where ϕ_0 is the latitude on the origin (38.0 degrees), etc.

Easting and northing coordinates expressed in meters can be computed as described in Table 7-9.

Table 7-9. Easting and northing calculation

Easting (m)	=	$\rho\ sin\ [n\ (\lambda - \lambda_0)\ ]$ + False Easting
Northing (m)	=	$\rho_0 - \rho\ cos\ \theta$

Here, ρ is computed using the latitude of the location to be converted to Ohio State Plane south coordinates, and FE is the false easting for the coordinate system. Also, λ is the longitude of the location to be converted to Ohio State Plane South coordinates, and λ_0 is the longitude of the origin of the Ohio State Plane South coordinate system. All angles must be expressed in radians, and all west longitudes are negative angles.

The Ohio State Plane South system coordinates are generally expressed in U.S. survey feet. To obtain the true northing and easting values, the equations in Table 7-10 apply.

Table 7-10. Conversion from feet to U.S. survey feet

Easting (ft)	=	Easting(m) * (1200/3937)
Northing (ft)	=	Northing (m) * (1200/3937)

Note: The U.S. survey foot is approximately 2 parts in 1,000,000 larger than the standard U.S. foot.

7.2 NaI Automatic Energy Calibration (EGAS Method)

The NaI software (both NaI and the NaI portion of the EMS software) uses a peak tracking technique to examine and automatically account for spectrometer gain drifts that are common to NaI systems. The NaI software keys on the 1460.8 keV K-40 and 2614.6 keV Tl-208 gamma ray lines for energy calibration calculations during field operations. The basis and methodology of the automated energy calibration techniques used at the FCP are described in this section.

RTIMP operations procedures normally require that all NaI data be collected with a real or clock time of four seconds, as opposed to a "live time" of four seconds. A typical background spectrum collected at FCP may have less than 15 events (counts) in the spectral region of interest around 2614 keV.

So multiple spectra are added together to increase the statistical probability of correctly identifying the centroid of the 1460 keV gamma ray peak from K-40 and the 2614 keV gamma ray peak associated with the Th-232 decay series. For the EMS, the default number of spectra to be summed is seventeen; but the user may change this value on the front panel of the main data acquisition display (Figure 5-3). The number of summed spectra is fixed at seventeen for the NaI software when any platform other than the EMS is used. The NaI software uses a sliding window of seventeen spectra (the prior sixteen spectra plus the current spectrum) to determine both multi-channel analyzer gain (i.e., energy calibration) and the spectral background. The counts in each corresponding channel of the seventeen spectra are summed to form a virtual spectrum, which has more statistical reliability because of the larger number of counts in each MCA memory channel. This virtual spectrum is "sanded" to estimate the spectral background continuum, as explained later in this document. The spectrometer gain is also determined from this virtual spectrum. It is important to note, however, that radionuclide concentrations reported by the real time software are based on the original unaltered spectra, not the virtual spectrum created from them.

The algorithm used to locate gamma ray peaks was translated from the EGAS provided by R.T. Reiman (Reiman 1995). First, the peak center is located by determining the maximum of the sum of four consecutive channels (a sliding window) in the area of the expected peak. If there are multiple occurrences of the maximum, the largest channel number is chosen. The peak of the four-channel window is taken at the second channel in the window to be consistent with EGAS. This operation is shown on Figure 7-1 in native LabView code. The initial starting channel for the four-channel summation and number of four-channel summations to perform are shown in Equations (1) and (2) respectively. They are based on the current gain and offset of the energy calibration (nominally 5.852217 keV/channel).

$$C_{start} = (0.92*E - E_{zero})/E_{cal} \quad (1)$$

$$N_{loops} = 0.16*E/ E_{cal} + 1 \quad (2)$$

where

C_{start}	=	The starting channel number.
E	=	Energy of the desired peak (keV).
E_{zero}	=	Energy offset at channel 0 of the energy calibration.
E_{cal}	=	Gain in keV/channel of the energy calibration
N_{loops}	=	The number of loops to execute looking for the maximum summation.

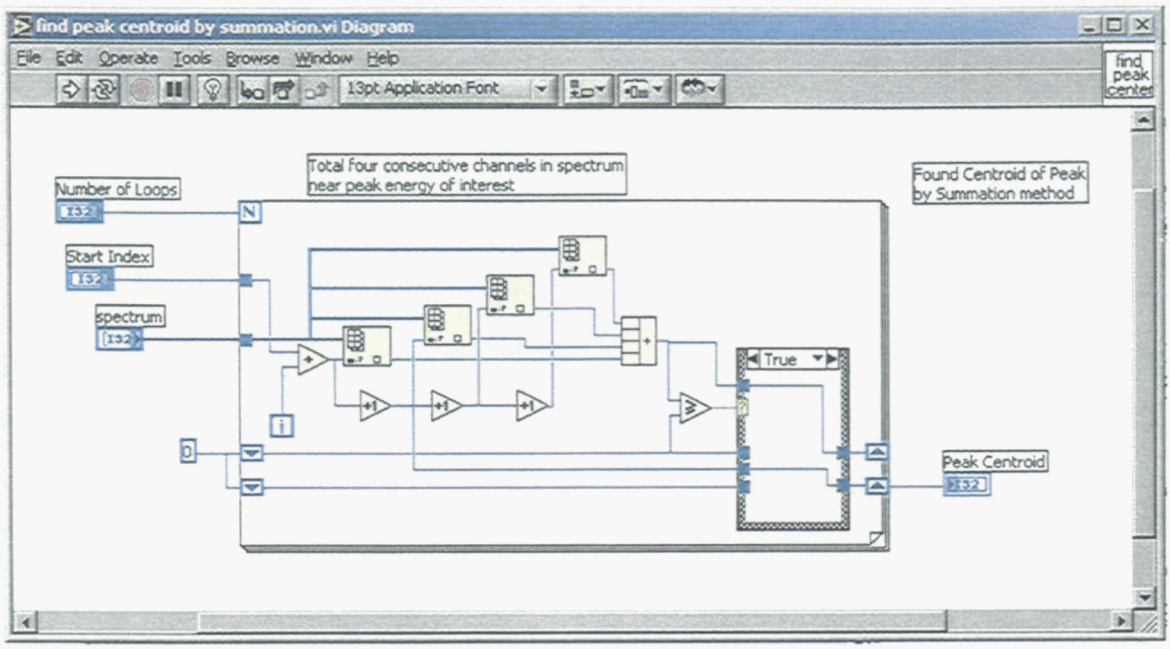

Figure 7-1. Algorithm to find peak center by summation

Once the approximate location of the peak centroid has been determined by the simple summation method, the centroid location is determined more accurately using a first moment calculation as shown in Equation (3).

$$P_{mom} = \frac{\sum_{i=A}^{B} i * S_i}{\sum_{i=A}^{B} i} \tag{3}$$

where

P_{sum}	=	Peak centroid by summation method
A	=	P_{sum} - 0.056*E/5.85
i	=	channel number
S_i	=	counts in the *i*th channel of the virtual spectrum S
B	=	P_{sum} + 0.056*E/5.85
P_{mom}	=	Peak centroid by first moment method

The sequence of determining an approximate peak centroid location by the four-channel summation method, followed by more accurately locating the centroid with a first moment calculation, is repeated until the result of the first moment calculation varies by less than one quarter of one channel. This normally occurs within one or two iterations. Once the channel numbers of two prominent gamma ray lines (1460 and 2614.6 keV, for example) have been determined, the slope ($Slope_{new}$ in keV/channel) and offset (Off_{new}, the y-intercept in keV units) of the new energy calibration is computed using a straight-line rise over run computation. The new or updated gain and offset are saved to disc as part of each spectral file and they are also reported in the log file.

7.2.1 Error Conditions

The NaI system energy calibration process establishes a relationship between the known gamma ray energies emitted by calibration sources and their peak centroid locations in terms of MCA memory channels. Based on a typical energy calibration, isotopes commonly encountered in field measurements will normally produce peaks at expected locations across the energy spectrum. However, for various reasons, the system energy calibration can change slightly, so that peaks don't always appear in their expected positions. This is refereed to as "drift." When the drift becomes too large, the isotope which gives rise to the peak may not be properly identified because the peak centroid does not have the expected energy. That is, the peak centroid does not appear in the expected channel. The NaI software informs the user of this condition by generating energy calibration error codes when designated peak centroids are more than 15 channels above or below their expected locations. If the final computed peak centroid is outside of this window, the energy calibration module returns an error condition and internally sets the peak centroid to the channel number computed using the default gain and offset of 5.852217 keV/channel and –1.3408866 keV. The NaI code advises the user of the error condition. The code uses the default gain if the error occurs on the calibration spectrum. If the error occurs during normal data acquisition, the NaI code logs the error, displays an alarm to the user, and uses the calibration gain calculated from the previous block of summed spectra.

7.3 NaI Spectral Stripping

The NaI code extracts the net count rates from four windows in each spectrum to determine activity for Th-232, Ra-226, K-40, and total uranium. Because spectra are energy calibrated in real-time, the windows used to extract count rates must also be adjusted to account for energy shifts. This section describes this process.

The stripping windows (or regions-of-interest) that correspond to a default energy calibration of 5.852217 keV/channel and offset of –1.3408867 keV are shown in Figure 7-2. Figure 7-2 shows the starting and ending signal channel numbers for the thorium, radium, uranium, and potassium ROIs. For example, the thorium signal window starts at channel number 411 and ends at channel 483.

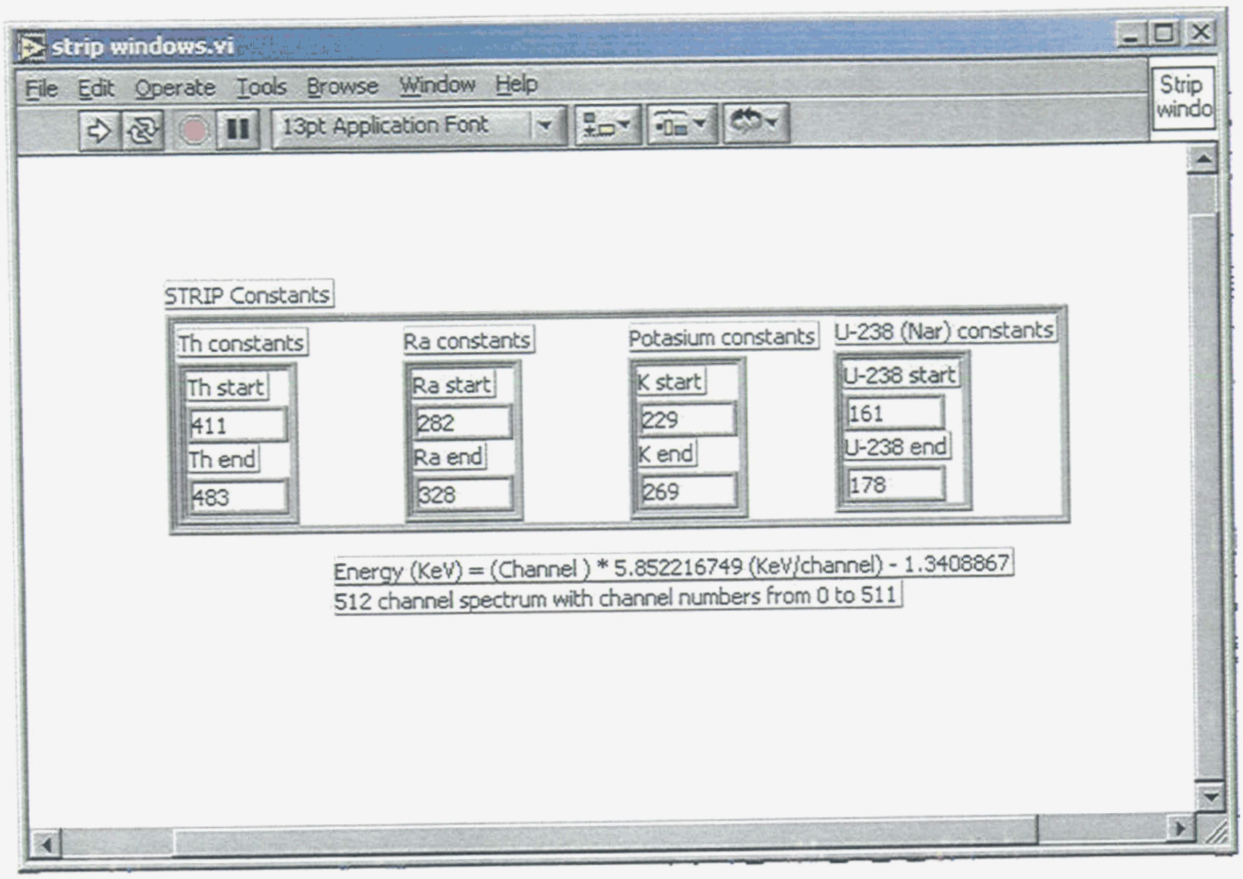

Figure 7-2. Strip windows based on the default energy calibration

The strip windows shown in Figure 7-2 are modified to account for any energy calibration drifts (described in Section 7-2). The windows are shifted based on the number of channels required to move both the start and end channel numbers of the signal window to match the adjusted energy calibration. This is shown in Equation (4).

$$C_{new} = \frac{[C_{default} * 5.852217 - 1.3408867] - Off_{new}}{Slope_{new}} \tag{4}$$

where

C_{new}	=	Adjusted signal window channel rounded to the nearest integer.
$C_{default}$	=	Default signal window channel (e.g., 411 for Th-232)
Off_{new}	=	New energy calibration offset (keV)
$Slope_{new}$	=	New energy calibration gain (keV/channel)

The amount of adjustment required will normally be slightly different for the four ROIs depending on the energy calibration. Separate signal window adjustments are computed for the thorium, radium, potassium, and uranium ROIs.

7.3.1 NaI Sanding of the Background Spectrum

The background spectrum is a virtual spectrum constructed from the previous sixteen spectra plus the current spectrum. Since each spectrum is a four second (true time) spectrum, the background spectrum is normally between 60 and 65 seconds (live time) long assuming an analyzer dead time of between 5 and 10 percent. This spectrum is the same spectrum used for the automatic energy calibration process described in Section 7.2. Sanding is a data analysis technique used to estimate the continuum of a spectrum. This is done by smoothing (or sanding) the spectrum in a series of operations that compare the average of the counts in a specific window of the spectrum to the value of the counts in the center channel of that window. The window size is related to the resolution of the detector and is carefully chosen such that it is slightly larger than the detector resolution. Since the detector resolution changes with energy, the window size, or size of the "sandpaper" is also a function of energy and is constantly increasing in size as the process proceeds from the lower channels to the upper channels of the spectrum. Figure 7-3 shows the relationship between detector resolution (photopeak base width) and energy for a typical 4x4x16-inch sodium iodide detector.

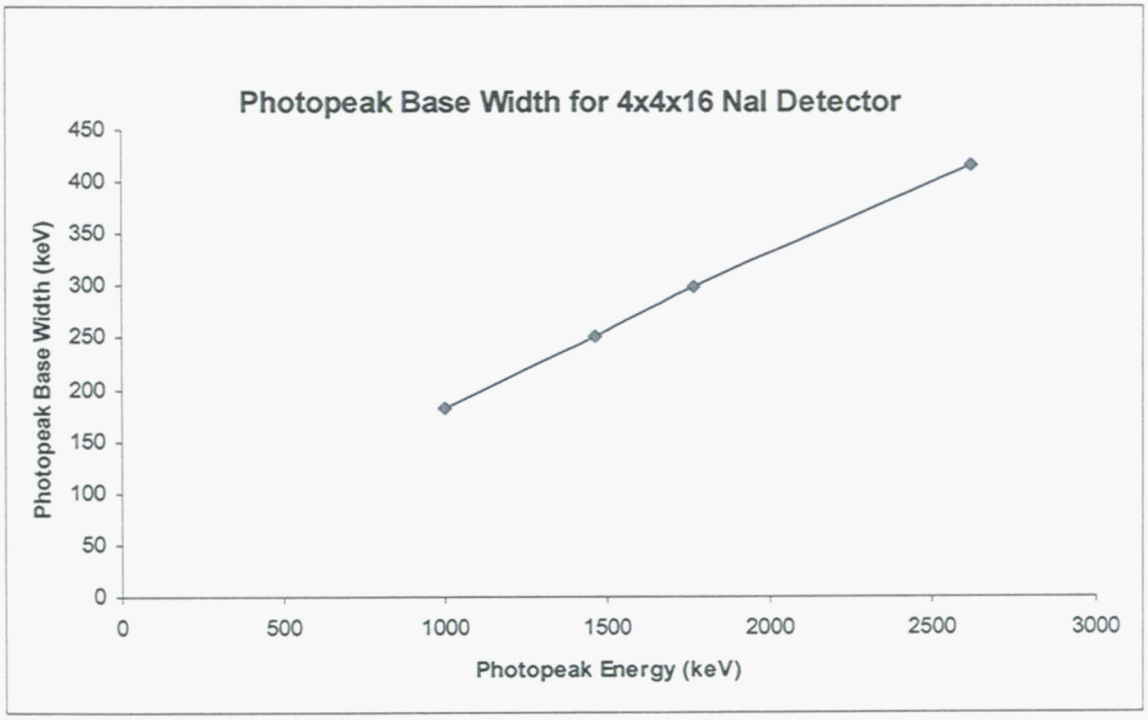

Figure 7-3. Typical detector resolution as a function of energy

The relationship shown in Figure 7-3 has been modeled as shown in Equation 5.

$$Base = 0.1446844488 * E + 37.975134916 \tag{5}$$

where Base = detector resolution in keV

E = energy in keV.

Detector resolution can be converted to number of channels by using the current energy calibration parameters, subtracting the energy calibration offset and dividing the result by the slope of the energy calibration. The sanding algorithm requires that the number of channels used for the sand size must be an odd number. An odd number of channels ensures the channel location of the average counts across the

sand window corresponds to the center channel of the sanding window. The average of the signal counts per channel in the channels of the sanding window is shown in Equation 6.

$$A_{sw} = \frac{\sum_{j=0}^{sw} S_{(n-\frac{sw}{2}+j)}}{sw} \tag{6}$$

where,

sw	=	Number of channels in the sanding window (from Equation 5),
n	=	Channel number in the spectrum where "sanded counts" are being determined,
A_{sw}	=	"Sanded counts" in channel n, which is equal to the average number of counts per channel in the sanding window centered on channel n,
$S_{(x)}$	=	Counts in channel number ***x*** of the background spectrum.

If the value of the sanded counts is less than the value of the counts in channel ***n***, replace the counts in channel ***n*** by the sanded counts. The sanding process is performed for all channels in the spectrum from channel 5 through channel 511, the last channel in the NaI spectrum. The entire sanding process is repeated 20 times. The sanding process, expressed as a mathematical formula is described in Equation (7).

$$\sum_{i=1}^{20}\sum_{n=5}^{511}\left(if\left[\frac{\sum_{j=0}^{sw} S_{(n-\frac{sw}{2}+j)}}{sw} < S_n\right] then\left[S_n = \frac{\sum_{j=0}^{sw} S_{(n-\frac{sw}{2}+j)}}{sw}\right]\right) \tag{7}$$

7.3.2 NaI Stripping Mechanics

Once the strip windows have been appropriately adjusted for any gain changes that may have occurred, and the background spectrum has been sanded to approximate the continuum, the background count, the gross signal count, and the net signal count are calculated for each of the four ROIs. The sanded spectrum must be normalized by the ratio of the live time of the signal spectrum to the composite (or virtual) live time of the sanded spectrum before the background count can be calculated. After properly normalizing the sanded background spectrum, the gross count in each ROI is computed as the sum of the counts in all channels of the ROI as shown in Equation (8).

$$C_{sig} = \sum_{i=R_{start}}^{R_{end}} S_i \tag{8}$$

where

C_{sig}	=	Total counts in the signal ROI.
R_{start}	=	ROI start channel number.
R_{end}	=	ROI end channel number
S_i	=	Counts in the *i*th channel of the signal ROI

The background counts for each corresponding ROI are computed in a similar manner, using data in the normalized sanded spectrum, as shown in Equation (9).

$$C_{back} = \frac{LT_{sig}}{LT_{back}} \sum_{i=R_{start}}^{R_{end}} S_i \tag{9}$$

where

S_i, R_{start}, and R_{end} are as defined above and

LT_{sig} = Live time of the signal spectrum (nominally a 4-second spectrum).

LT_{back} = Live time of the virtual background spectrum (approximately a 60-second spectrum).

For each ROI, the net count is the gross count minus the background count, and the net count rate is the net count divided by the live time of the signal spectrum as shown in Equations (10) and (11).

$$C_{net} = C_{sig} - C_{back} \tag{10}$$

$$U_{cps} = \frac{C_{net}}{LT_{sig}} \tag{11}$$

where

C_{net} = Net count in the ROI.

U_{cps} = Net count rate in the ROI.

7.4 NaI Computational Algorithms

The NaI software calculates U-238, Th-232, Ra-226 and K-40 activity concentrations in pCi/g and total uranium concentrations in ppm for each spectrum. The code also computes the measurement uncertainty and the MDCs of each of the contaminants listed above for each spectrum. The details of these computations are described below.

7.4.1 Activity Computation

When any of the isotopes mentioned above is present in the soil, it gives rise to a characteristic energy peak in the gamma ray spectrum. The measured activity concentration of a contaminant isotope is proportional to the net area of the corresponding characteristic spectral peak. The net peak areas (NPAs) extracted from the stripping algorithms are converted to isotopic net count rates by dividing the total net counts in each peak by the spectral acquisition time (i.e., the live time). The net count rates are converted into activities by using a series of equations provided by the FCP (DOE 2001). These equations are described briefly in Table 2-6 and represented graphically in Figure 7-4. Essentially the net peak count rates (Thcps, Racps, Kcps, and Ucps in Figure 7-4) are multiplied by the coefficients provided in the ***nai-coef.txt*** file (Table 2-6) to arrive at individual radionuclide activity concentrations. However, these concentrations are based on "as is" or "wet" soil weights. Before the measured activities can be used for any purpose, they must be converted to dry weight results. The algorithm shown in Equation (12) is used to convert from wet weight results to dry weight results.

$$A_{mc} = A * (1.0 + Txm) \tag{12}$$

where

A_{mc} = Moisture corrected activity

A = Raw activity (not moisture corrected)

T_{xm} = Soil moisture meter reading expressed on a dry weight basis in decimal format

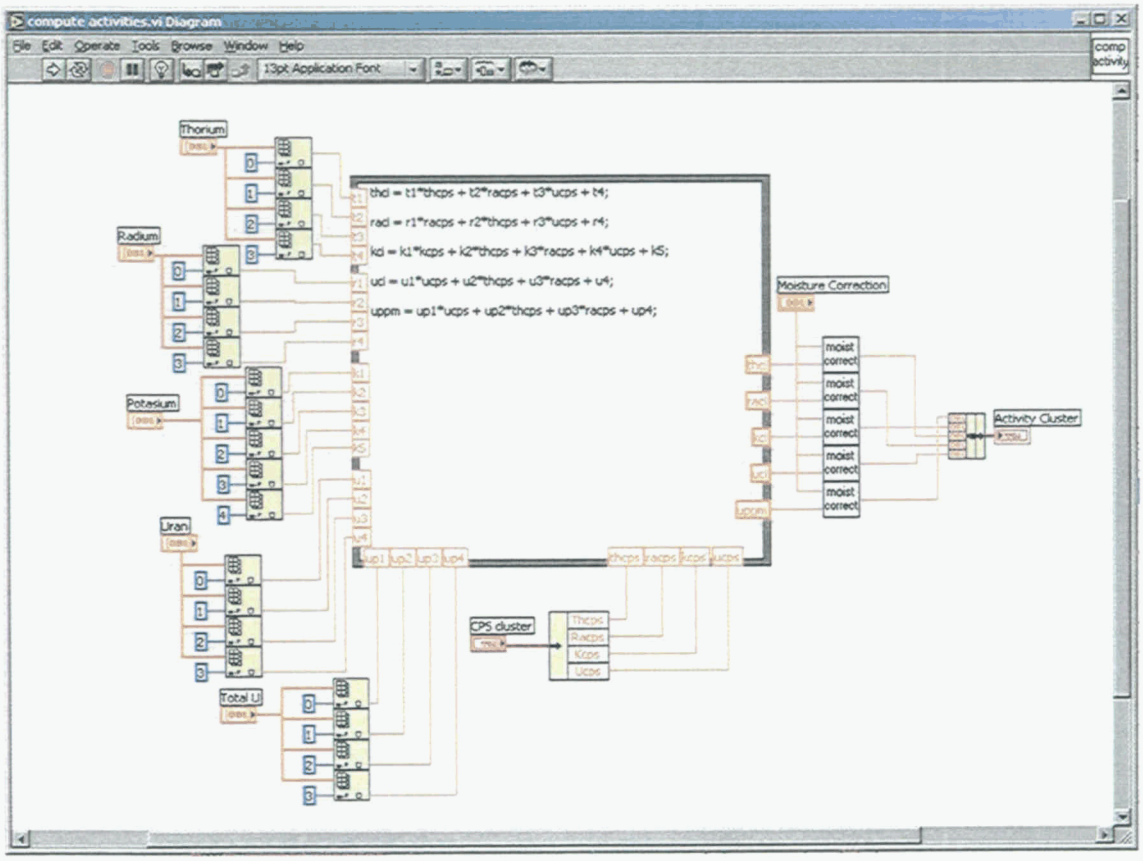

Figure 7-4. LabView source code NaI activity computation

7.4.2 NaI Minimum Detectable Concentration Computation

MDCs are also computed, and reported in the summary log file, for each spectrum for uranium, thorium, potassium and radium. These calculations are based on the NaI measurement uncertainty analysis performed by ANL personnel (Davis 2004). Equation (13), shown below, provides an example MDC calculation for uranium. The MDC computation involves using the detection limit of the primary isotope of interest (U-238 in this example, expressed as counts per second) along with the net count rates of the secondary isotopes (obtained from a background spectrum) in the activity calculation equation shown in Figure 7-4. The coefficients of the various count rate terms in the MDC calculation are the same as those used in the activity computations depicted in Figure 7-4. As noted above, they are stored in a file named ***nai-coef.txt***, an example of which is shown in Table 2-6. These coefficients depend upon the primary isotope of interest and the particular NaI system. The MDC algorithms are represented graphically in Figure 7-5. The basic computation for uranium is presented below in Equation (13):

$$U_{MDC} = U_1 \times U_{Ld} + U_2 \times Th_{Ncps} + U_3 \times Ra_{Ncps} + U_4 \tag{13}$$

where U_{MDC} = Uranium minimum detectable concentration in pCi/g,

U_{Ld} = Uranium detection limit count rate (cps),

U_1 = First coefficient in uranium coefficient file,

Th_{Ncps} = Thorium signal net count rate determined from a background spectrum,

U_2 = Second coefficient in uranium coefficient file,

Ra_{Ncps} = Radium signal net count rate determined from a background spectrum,

U_3 = Third coefficient in uranium coefficient file,

U_4 = Fourth coefficient in uranium coefficient file.

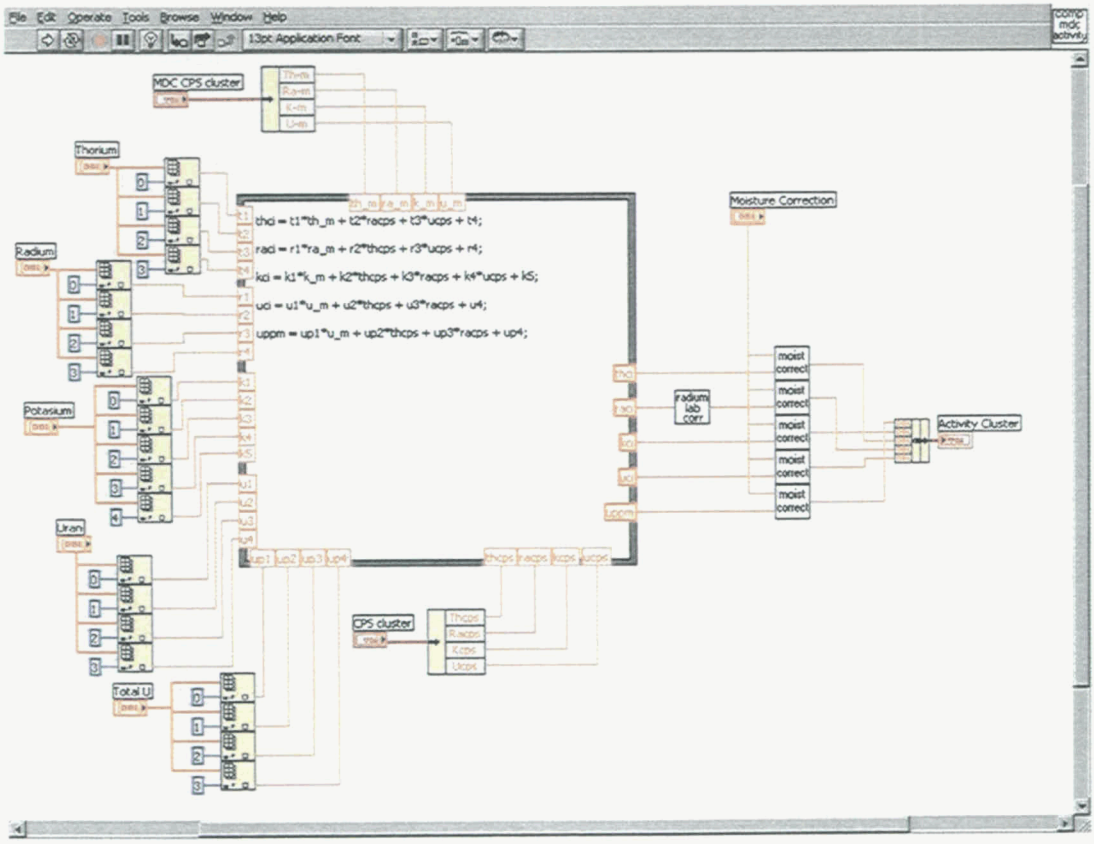

Figure 7-5. NaI real-time code MDC calculation

The 95% detection limit count rate (L_d) can be calculated using the algorithms provided in Reference 7 and shown in Equations (14) through (16).

$$L_d = \frac{[-b]}{LT} \tag{14}$$

where

L_d = Detection limit count rate

b = Coefficient calculated in Equation (15)

LT = live time of the spectrum

$$b = -\{2L_c + 1.645^2(d+1)\} \tag{15}$$

where

L_c = Critical level calculated in Equation (16)

d = Slope for the given nuclide derived from calibration data (see Table 7-11)

$$L_c = 1.645\sqrt{2 * \mu_{G0}} \tag{16}$$

where

μ_{G0} = Gross counts in the signal window

Table 7-11. Nuclide specific slope values for the MDC calculation

	d (slope)
Uranium	0.445
Radium	0.170
Thorium	0.053
Potassium	0.000

7.4.3 NaI Uncertainty Computation

The NaI code calculates the measurement uncertainty at the 95% confidence level for each calculated isotopic concentration in every spectrum collected. Equation (17) shows the calculation used to arrive at the uncertainty in the net count rate. ANL personnel provided this methodology after analysis showed that main component of uncertainty is associated with the uncertainty in gross count rate.[7]

$$CR_{unc} = \frac{1.645}{LT}\sqrt{\mu_{GO}} \tag{17}$$

where

CR_{unc} = Net count rate uncertainty (cps)

The uncertainty in the measured concentrations of thorium, radium, uranium, and potassium (95% confidence level) in pCi/g (or ppm) can be calculated by substituting the net count rate uncertainties into Equations (18) through (22) where the coefficients for uranium, thorium, radium, and potassium are those provided in Table 2-6.

$$Th_{unc} = \sqrt{(T_1 * Th_{cr})^2 + (T_2 * Ra_{cr})^2 + (T_3 * U_{cr})^2} \quad (18)$$

$$Ra_{unc} = \sqrt{(R_1 * Ra_{cr})^2 + (R_2 * Th_{cr})^2 + (R_3 * U_{cr})^2} \quad (19)$$

$$K_{unc} = \sqrt{(K_1 * K_{cr})^2 + (K_2 * Th_{cr})^2 + (K_3 * Ra_{cr})^2 + (K_4 * U_{cr})^2} \quad (20)$$

$$U238_{unc} = \sqrt{(U_1 * U_{cr})^2 + (U_2 * Th_{cr})^2 + (U_3 * Ra_{cr})^2} \quad (21)$$

$$Utot_{unc} = \sqrt{(Ut_1 * U_{cr})^2 + (Ut_2 * Th_{cr})^2 + (Ut_3 * Ra_{cr})^2} \quad (22)$$

where

Th_{cr}	=	Thorium net count rate uncertainty using Equation (17)
Ra_{cr}	=	Radium net count rate uncertainty using Equation (17)
U_{cr}	=	Uranium net count rate uncertainty using Equation (17)
K_{cr}	=	Potassium net count rate uncertainty using Equation (17)
Th_{unc}	=	Uncertainty in the thorium concentration in pCi/g at the 95% confidence level
Ra_{unc}	=	Uncertainty in the Radium concentration in pCi/g at the 95% confidence level
K_{unc}	=	Uncertainty in the Potassium concentration in pCi/g at the 95% confidence level
$U238_{unc}$	=	Uncertainty in the U-238 concentration in pCi/g at the 95% confidence level
$Utot_{unc}$	=	Uncertainty in the Total Uranium concentration in parts per million at the 95% confidence level

7.4.4 NaI Radium Correction for Soil Radon Loss

All calculated radium values are corrected for soil radon loss using the correction process provided in Section 5.6 of the User Guidelines (DOE 2004b). This correction is applied to the nominal radium concentration, the radium MDC value, and the radium uncertainty value. The correction for soil radon loss is empirically derived and shown in Equation (23). The radon correction must be applied before the moisture correction factor is applied.

$$Ra_c = 0.551 * Ra_u + 0.46018 * Ra_u^{\,2} \quad (23)$$

where

Ra_c	=	Radium value corrected for soil radon loss.
Ra_u	=	Uncorrected radium value

7.5 HPGe Radium Correction for Soil Radon Loss

The HPGe code relies primarily on a subset of the EGAS analysis module to perform all activity calculations including automated energy calibration of the spectra, stripping of the regions of interest, and conversion from raw counts per second to activity. However, the HPGe real-time software does perform the laboratory radium correction to the EGAS-calculated Ra-226 result. The empirically derived radium correction algorithm for HPGe systems is also discussed in Section 5.6 of Reference 8. It is shown below

in Equation (24). This correction must be applied before performing the moisture correction shown in Equation (12).

$$Ra_c = 0.98438 * Ra_u + 0.34651 * Ra_u^{\ 2} \tag{24}$$

where Ra_c and Ra_u are as defined below Equation (23).

7.6 HPGe Quality Assurance and Duplicate Checks

All HPGe codes perform automated QA checks for consistency in a single spectrum and consistency across duplicate spectra as required by FCP procedures. Codes performing these checks are the HPGe single spectrometer code, the HPGe side of the EMS code, and the HPGe Reprocessor code embedded in the FCP Master Utility Code.

7.6.1 Multi-Line Isotope Analysis

The EGAS analysis engine generates calculated activities using every identified gamma-ray line specified in a user configurable file. Specifically, multiple lines for Uranium-238, Radium-226, and Thorium-232 are used to calculate measured activities. FCP personnel examine the calculated activities from the various peaks for consistency. Version 3.1 of the HPGe software automatically performs these checks as the spectral report files are generated. An example report file from EGAS is provided in Table 6-8 of this report. Each isotope has a designated primary gamma-ray line and two secondary lines as shown in Table 7-12.

Table 7-12. Low and High Energy Peaks Checked for Consistent Activities

ISOTOPE	Primary Line	Secondary Line	Tertiary Line
U-238	1001.0 KeV	63.2 KeV	92.6 KeV
Th-232	911.1 KeV	338.3 KeV	583.1 KeV
Ra-226	1120.4 KeV	351.9 KeV	609.3 KeV

The EGAS code calculates an activity and associated uncertainty for each available line in Table 7-12. EGAS does not calculate an activity or uncertainty for any line that is not discernable by the peak search engine. QA codes are set in the summary file (Table 6-7, Column AN) using the following criteria.

- If the primary line is missing, the low-energy versus high-energy activity cannot be compared, and the QA code is set to 3.
- If the primary line is available and both secondary and tertiary lines are available, an error-weighted activity is computed using the secondary and tertiary lines as shown in Equation 25. If the error-weighted activity is at least 80% of the primary line activity, the primary line activity is considered valid and the QA code is set to 0 (result OK). If the error-weighted activity is less than 80% of the primary line activity, the result is suspect and the QA code is set to 2. This will require a FCP technician to manually examine the spectrum at which point the result may be rejected or accepted.
- If the primary line is available and only the secondary or tertiary line is available, the subordinate line activity must be at least 80% of primary line activity for the result to be acceptable. If not, a QA code of 2 (result is suspect) is generated forcing the technician to manually examine the spectrum.

$$W_act = \frac{\left(\frac{A_2}{U_2^{\,2}} + \frac{A_3}{U_3^{\,2}}\right)}{\left(\frac{1}{U_2^{\,2}} + \frac{1}{U_3^{\,2}}\right)} \tag{25}$$

Where, W_act = Error-weighted activity

A_2 = Secondary line activity reported by EGAS

U_2 = Uncertainty in A_2 value reported by EGAS

A_3 = Tertiary line activity reported by EGAS

U_3 = Uncertainty in A_3 value reported by EGAS

7.6.2 Duplicate Code Check

FCP procedures require that duplicate spectra be collected on a regular basis during field operations. Duplicate spectra are defined as spectra that are collected over identical locations. Consecutive duplicates are collected "back-to-back" and non-consecutive duplicates occur when the HPGe equipment is moved to another location and then back to the original spot for the duplicate measurement. Duplicate spectra are checked to see if the results are consistent. However, the acceptance criteria differ, depending upon whether consecutive or non-consecutive duplicates are being compared and whether the measured activities are near MDC or well above MDC. The MDC referred to in the previous sentence is t he *a priori* minimum detectable concentration for the HPGe systems, which are determined annually. Three conditions are checked, with the results being indicated by the QA codes reported in column AO of the HPGe summary file (Table 6-7). The default *a priori* MDCs are provided in Table 4-2. These checks can be summarized as follows.

- The first check is to determine if all nuclides that exceed the *a priori* MDC are present at greater than MDC levels in both the duplicate and the original spectrum.
- The second check to is verify that the reported activities differ by less than MDC for nuclides where the activity is greater than one MDC but less than 5*MDC.
- The third check is to verify that, when the reported activity of either measurement is greater than or equal to 5*MDC, the relative percent difference between the reported activities is less than 20% for consecutive duplicates or less than 35% for non-consecutive duplicates. Relative percent difference (***RPD***) is defined in Equation 26.

$$RPD = \frac{abs(org - dup)}{(org + dup)/2} * 100 \tag{26}$$

where RPD = Relative percent difference between original and duplicate result

org = original measurement result

dup = duplicate measurement result

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8.0 FERNALD CLOSURE PROJECT MASTER UTILITY CODE

Several utilities that were previously available as individual executables have been combined into a single executable in the FCP Version 3.1 software suite. This was done primarily to improve QC with respect to installation updates as it is easier to track one code rather that six different codes, many of which share common modules. Although these utilities now exist in a single code, they have been developed as stand-alone modules that are simply called from a single driver. These utilities perform reprocessing of HPGe spectra, reformatting and analysis of native EGAS summary and report files into the standards presented in Section 4, the universal worksheet editor, reprocessing of NaI spectra, diurnal correction of both HPGe and NaI spectra, and a utility that simply displays HPGe QA codes in a fashion that is easy to read.

The front panel of the FCP Master Utility code is shown in Figure 8-1. It is designed such that the operator can finish one operation and jump to a second operation without exiting the software. Pressing the **EXIT UTILITY** button returns the user to the PCs operation system. Each of these options is described in the following subsections.

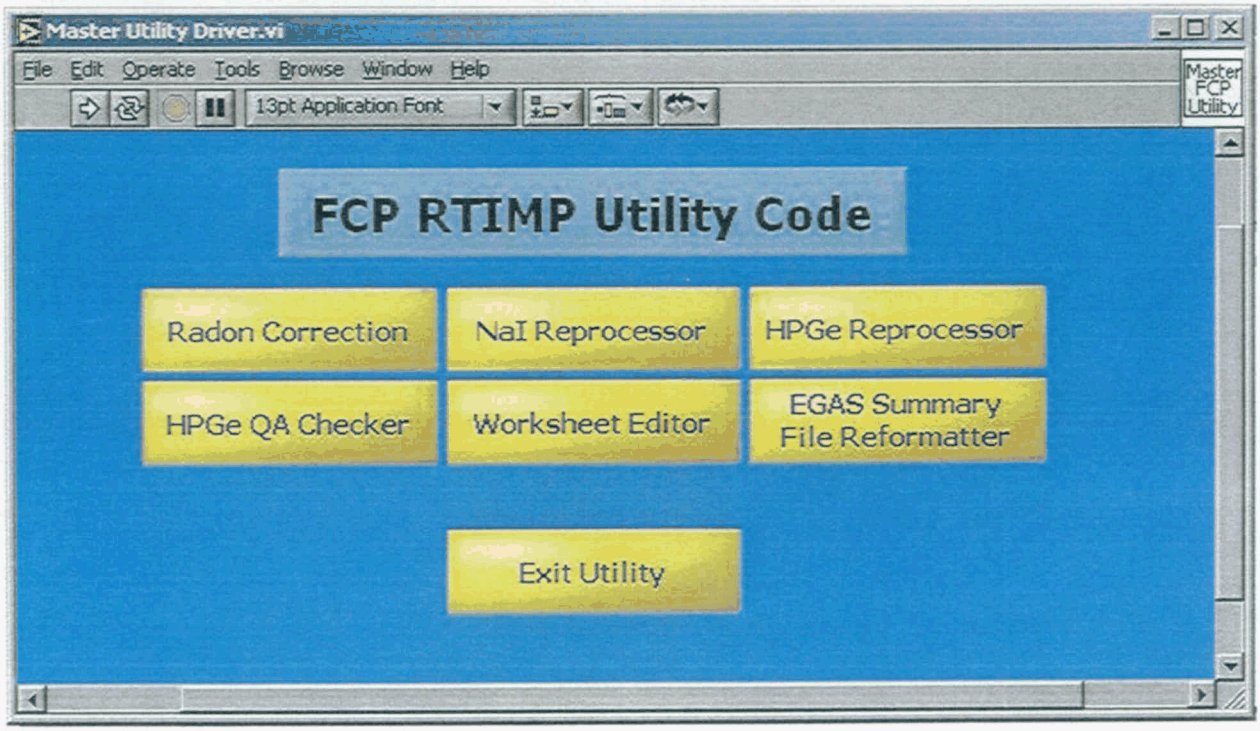

Figure 8-1. FCP RTIMP master utility code front panel

8.1 NaI Reprocessor

The NaI Reprocessor module is designed to reprocess raw sodium iodide spectra that were originally collected by the NaI software module described in Section 3 of this document. This is a menu-driven utility that can be used to recalculate sodium iodide activities when the field operating parameters were incorrectly entered, or some other condition has changed that requires the spectra to be re-analyzed. The front panel of the NaI reprocessor is shown in Figure 8-2. This panel will be presented to the operator along with a prompt instructing the user to select one of the NaI systems as shown in Figure 8-3. It is important that the system selected matches the detector used to collect the data because this sets the coefficients used in subsequent activity computations. Once the user acknowledges this

notification, the main panel is active allowing the user to change two operating parameters located on the main panel. The **Cal Window** control can be used to adjust the amount of drift in the energy calibration allowed by the software before reporting a calibration error. Under normal conditions, allowing calibration peaks to drift as many as 15 channels from normal default positions is a generous drift tolerance. However, there may be occasions where a system experiences a moderate energy drift or the instrument may not have been properly energy calibrated initially, and yet the data are deemed useable, despite the gain being outside of the normal tolerance limits. In such cases, FCP personnel may choose to widen the energy tolerance window to process these data and avoid going back to the field to re-acquire the spectral data. The **Spectrum Count** control can be used to change the number of spectra that are added together, channel by channel, to determine the detector energy calibration. In high activity areas, or areas with hot spots, it may be desirable to reduce the number of spectra used to determine the gain. The sliding window has an integrating or smoothing effect on the data, and pinpointing a hot spot location and extent may be easier if this window is reduced. Once the operator is satisfied with these settings, pressing one of the equipment selection buttons will provide the reprocessing coverage display shown in Figure 8-4.

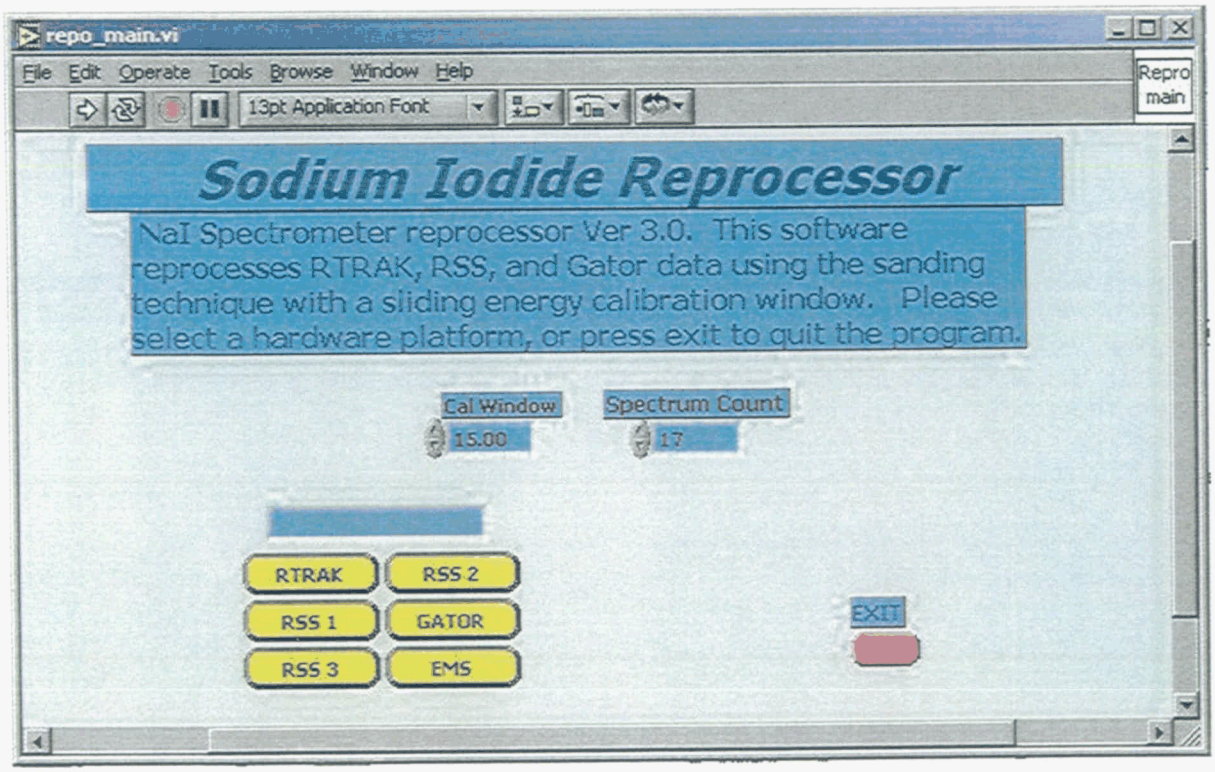

Figure 8-2. Sodium Iodide reprocessor main front panel display

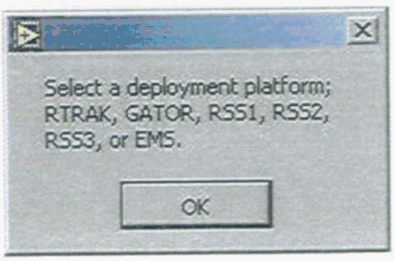

Figure 8-3. User prompt to select a NaI system

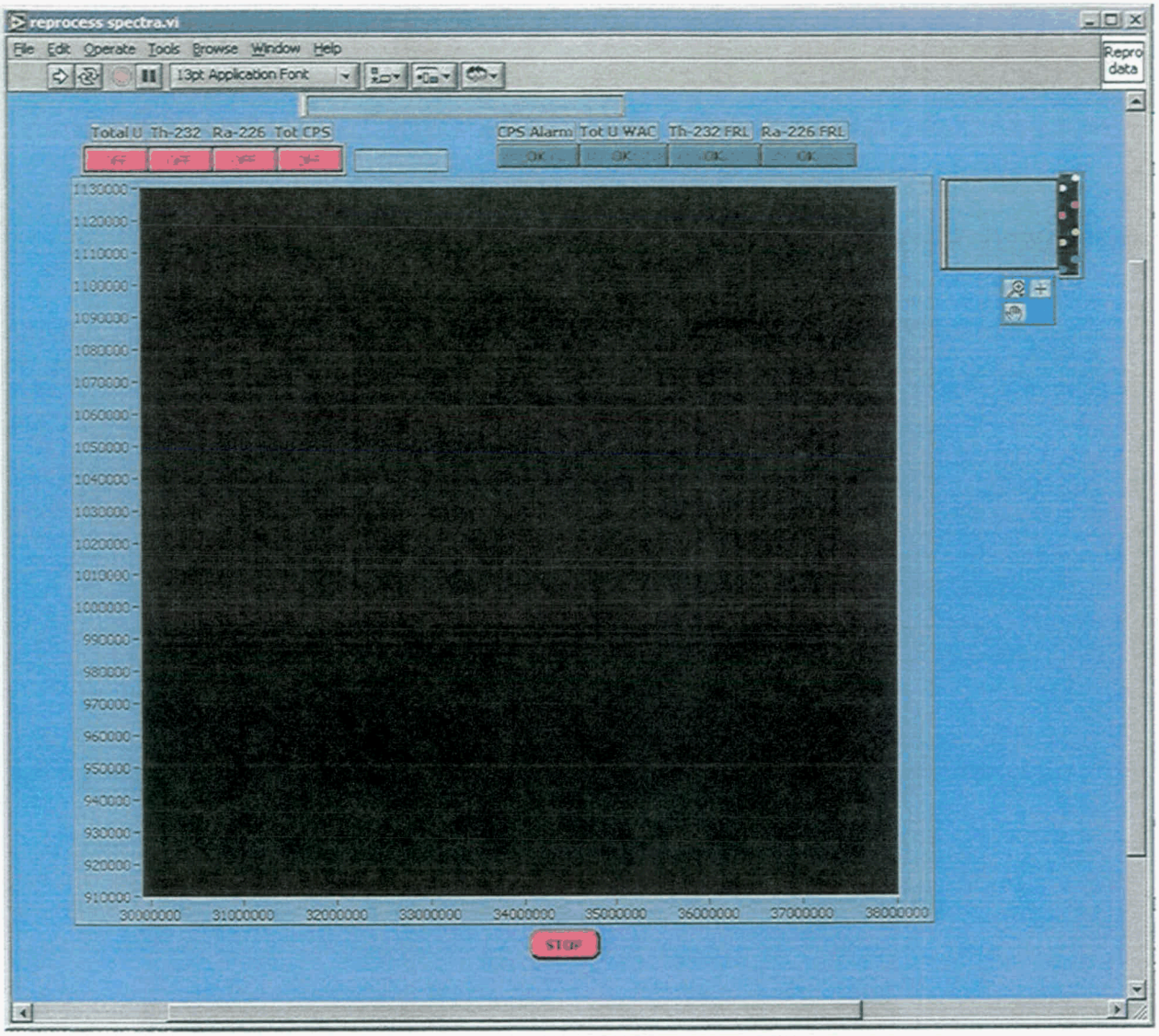

Figure 8-4. Reprocessed data areal coverage display

The data display panel operates similarly to the real-time NaI code X-Y data displays. The control located in the upper left-hand corner of the panel can be used to change the nuclide that is displayed on the large X-Y chart. The indicators located in the upper right-hand corner of the panel provide alarms when WAC and FRLs are exceeded. Immediately after this panel is shown to the user, the NaI reprocessor code will prompt the operator to locate the directory where the spectra to be reprocessed are located. This prompt, along with a prompt to locate the original log file associated with the spectra is shown in Figures 8-5 and 8-6. The original log file is used as a model to name the reprocessed log file, and as a starting point for placing the reprocessed log file and spectra in the directory structure of the computer running the reprocessor. For example, if the original log file was bldg_0001.log, the reprocessed log file will be named bldg_0001r.log

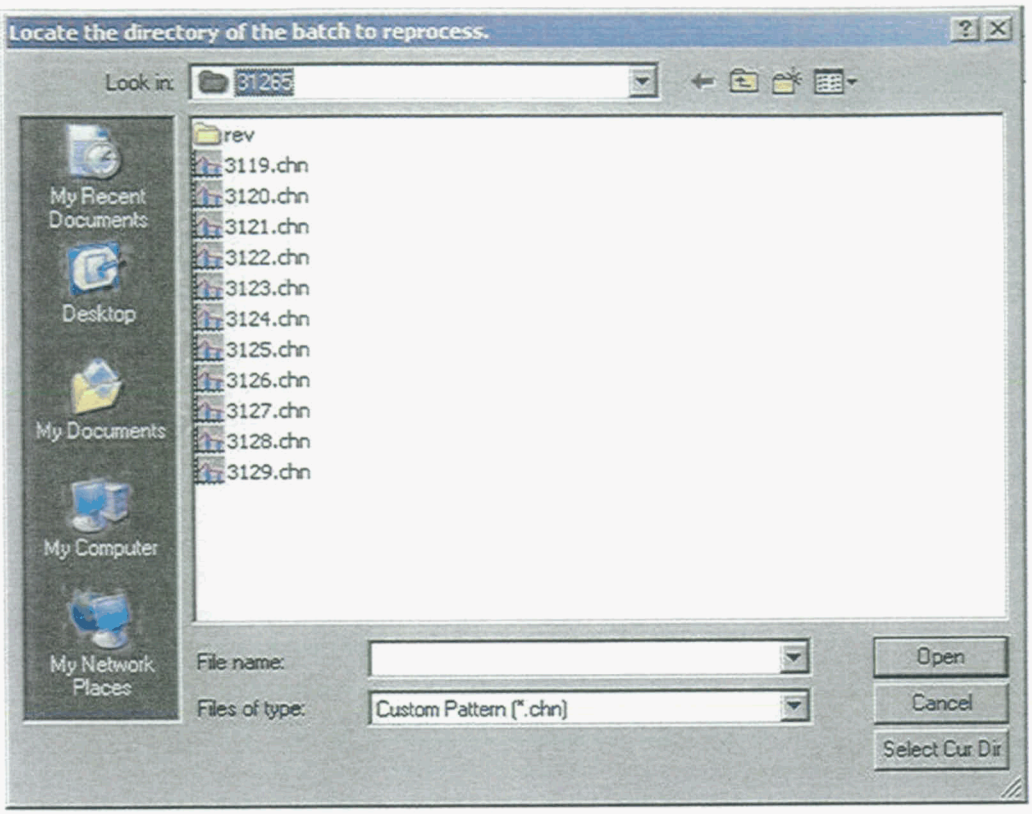

Figure 8-5. Panel used to prompt the operator to locate the directory where the spectra are located

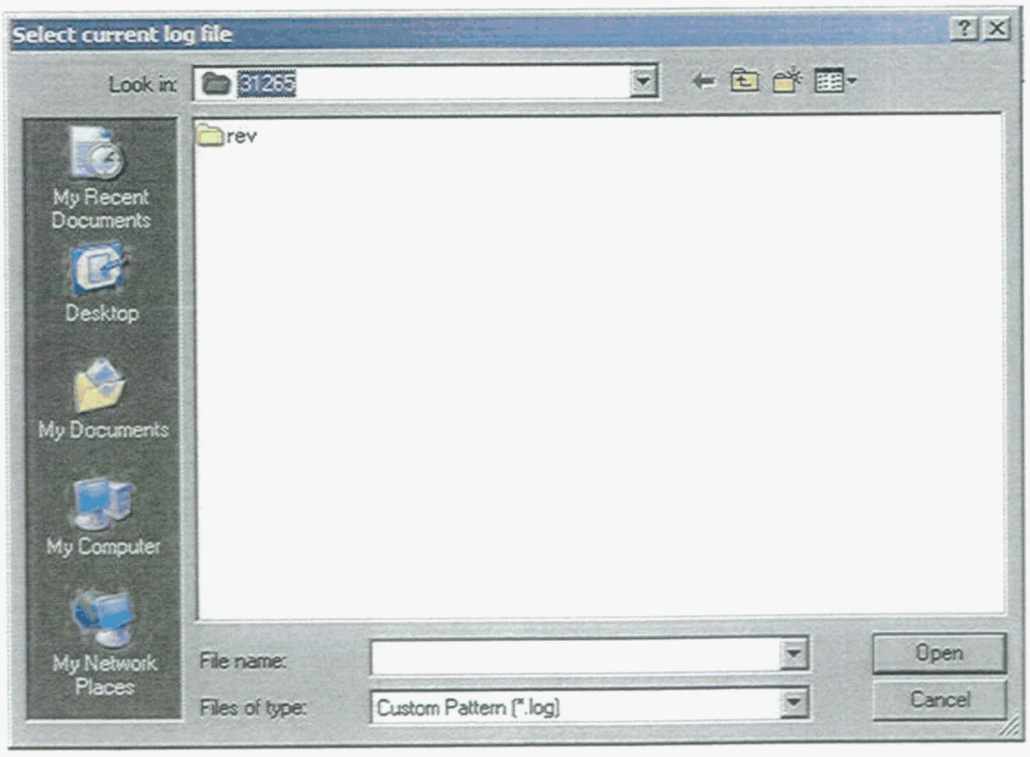

Figure 8-6. Panel used to prompt the operator to locate the current log file

Once, the log file is selected, the code will read the first spectrum in the batch and determine the moisture used to process the original data in the field. The reprocessor code will display the current moisture value and ask the operator if he wants to change this value as shown in Figure 8-7. If the operator selects **YES**, indicating that he wishes to change the current moisture value, the code displays the panel shown in Figure 8-8. The operator must enter a moisture value and click **OK** to proceed with reprocessing.

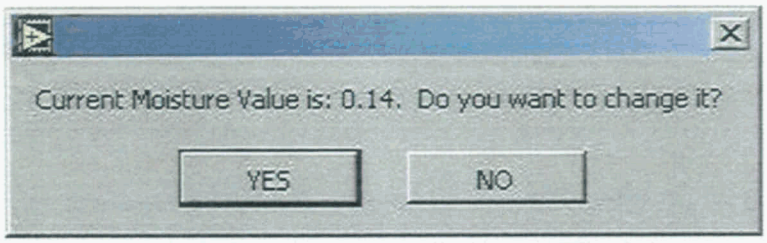

Figure 8-7. Prompt to change moisture value of batch

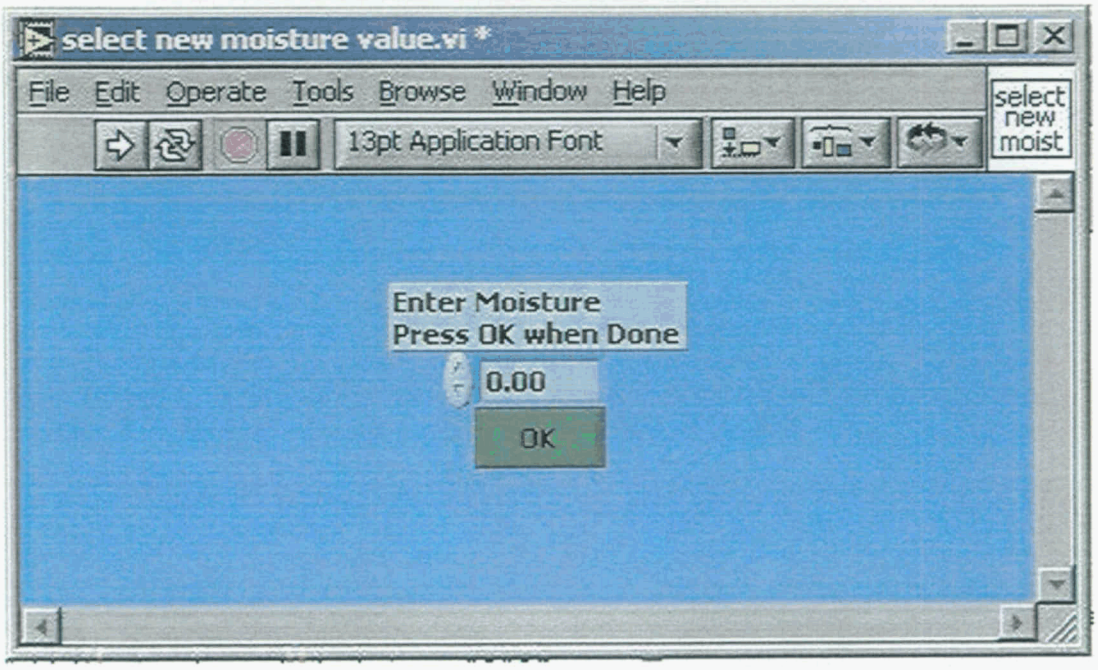

Figure 8-8. Panel used to change moisture value of reprocessed batch data

Next, the operator is prompted to decide whether to use the default regions of interest to perform the spectral stripping or to modify those ROIs (see Figure 8-9). This option is not for normal batch processing, but generally reserved for special analysis studies where the field conditions were abnormal. Normally, the user will select the "**Use Default**" button, but if the "**Modify**" button is selected, the software will display the panel shown in Figure 8-10 to allow the operator to modify the spectral stripping regions. The user can change the **start** and **stop** channels of each of the strip windows as desired. After making these selections, the operator must click "**FINISHED**" to accept these changes. Once this is done, the NaI reprocessor begins reading, striping, and analyzing spectra. A batch containing several hundred spectra will normally require several minutes to reprocess.

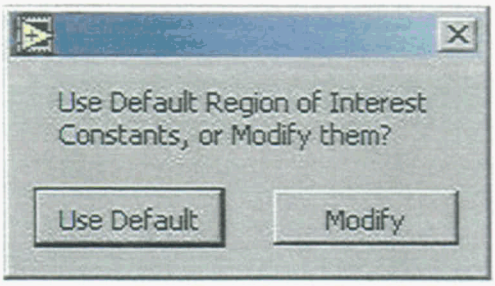

Figure 8-9. Prompt to change region of interest strip areas

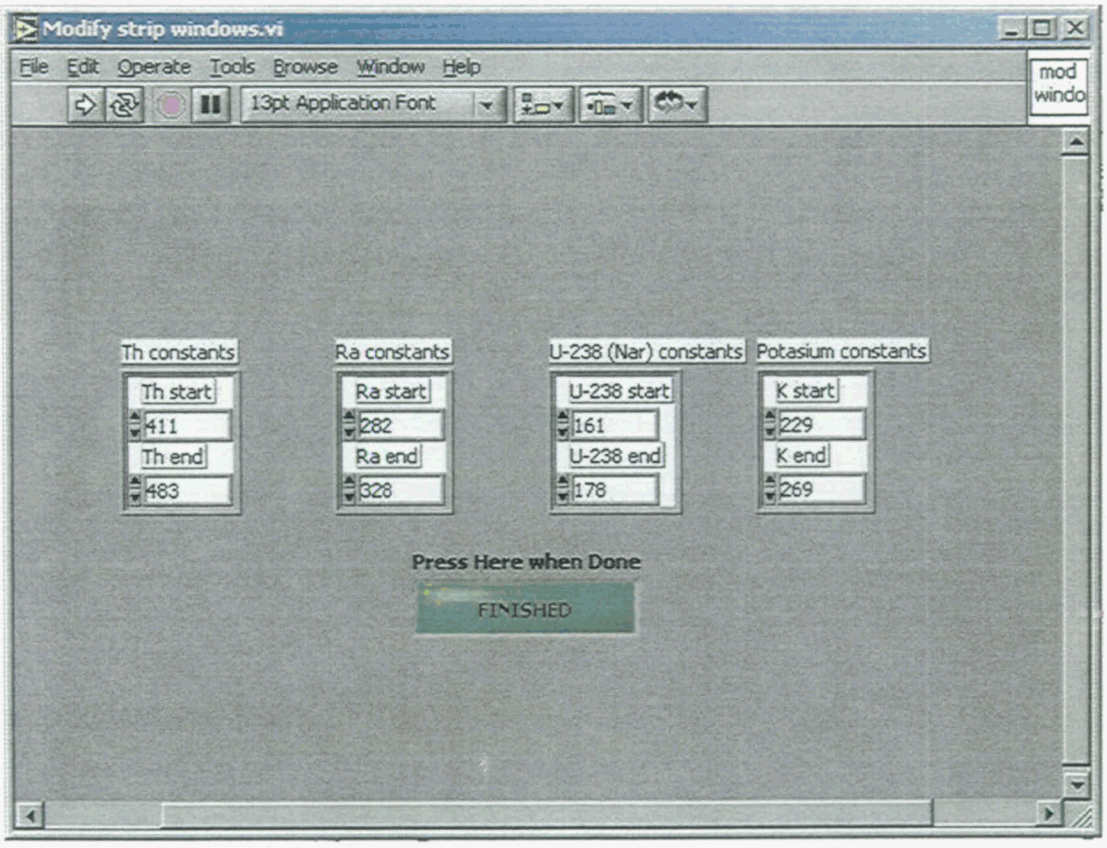

Figure 8-10. Front panel used to change the default region of interest strip areas

8.1.1 NaI Reprocessor File Output And Location

The NaI reprocessor code generates spectral files and a log file. These files follow the format described in Section 6.2 of this manual. All files are placed in a subdirectory of the location of the batch spectral files called, "revchn". All spectral files are renamed to indicate they have been reprocessed. An "_r" will be appended to the original spectrum file number. For example, if the file "3456.chn" is reprocessed, the reprocessor will create a new spectrum file named "3456_r.chn". The log file created by the reprocessor follows the same convention by adding an "_r" to the prefix of the original file name. This is done to distinguish the reprocessed spectra and log files from the original data collected in the field.

8.2 HPGe Reprocessor

The HPGe spectral reprocessor is designed to reprocess HPGe spectra in the event that GPS coverage was not available at the time of the data acquisition, or the data were collected using a GammaVision job file and not analyzed in the field using the real-time software. The front panel for the HPGe reprocessor is displayed (Figure 8-11) when the **HPGe Reprocessor** button is pressed on the main panel of the FCP master utility code (Figure 8-1).

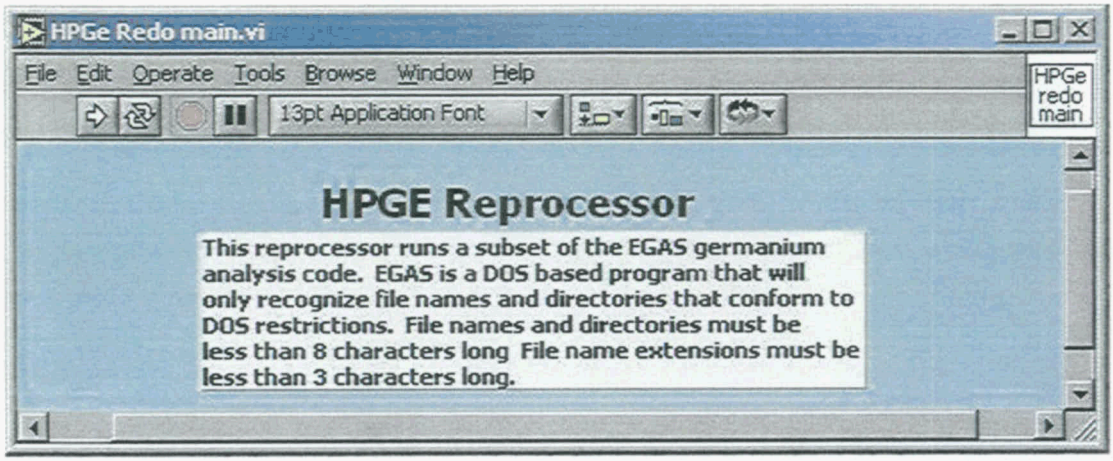

Figure 8-11. Main panel of the HPGe reprocessor code

The HPGe reprocessor uses a subset of the EGAS analysis engine to determine nuclide activity. EGAS is a DOS-based, 16-bit application that will not recognize directory structures and file names longer than 8 characters long. The HPGe reprocessor notifies the operator of this by requiring the operator to acknowledge the prompt shown in Figure 8-12.

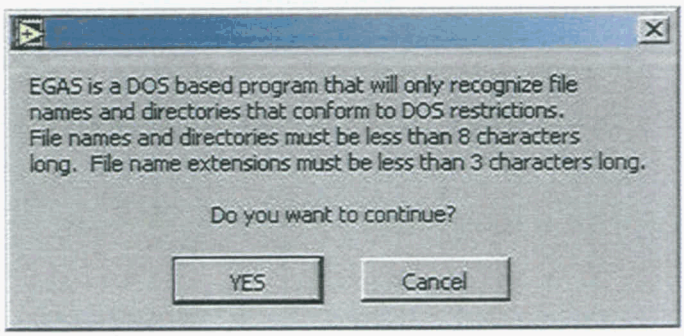

Figure 8-12. Acknowledgement prompt of DOS filename restrictions for the HPGe reprocessor

After the operator acknowledges the DOS limitations of the code, the operator is asked to locate the directory containing the spectra to be reprocessed. This is shown in Figure 8-13. After the appropriate spectral folder has been identified, the operator is asked to locate the HPGe coordinate file that will be used to update the sample description in each spectrum header. The coordinate file must be created prior to starting the Reprocessor. An example coordinate file is shown in Table 8-1. In order of appearance, the data columns in the coordinate file contain position coordinates expressed in terms of northing, easting, and elevation. The fourth column contains a unique location identifier, such as a flag number. A spectrum is selected for reprocessing only when the last three digits of the location ID string in a spectrum

file header in the designated storage folder matches a location ID in the HPGe coordinate file. The position coordinates associated with a matching location ID will be inserted into, or replace, the coordinates in the sample description header of the spectrum file. Duplicate spectra have an additional "-D" designator at the end of the location ID string in the spectrum header. However, the three digit numeric location ID in front of the duplicate designator is identical to that in the spectrum header of the original measurement (i.e., the first spectrum in the duplicate pair). This allows a single record in the coordinate file to be used for both the original and the duplicate spectrum when reprocessing the data.

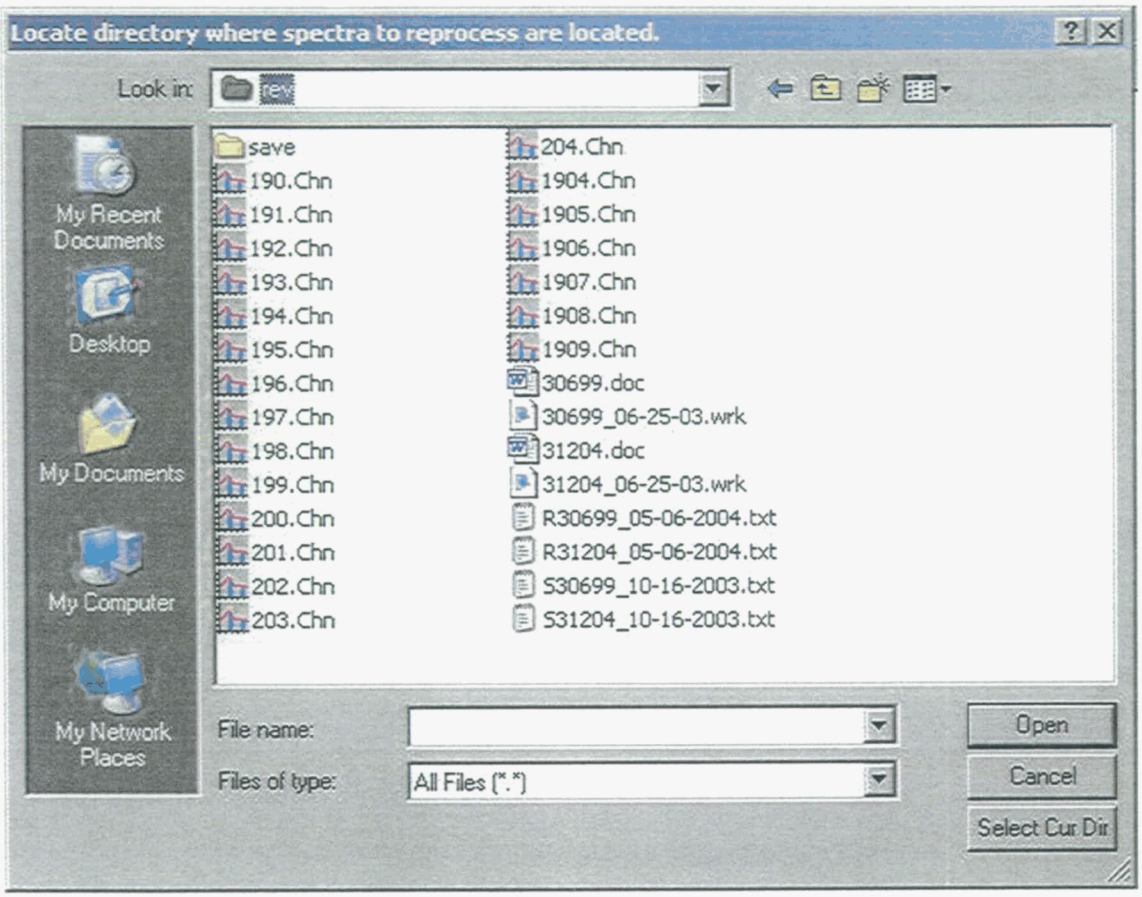

Figure 8-13. HPGe reprocessor prompt to locate spectra to reanalyze

Table 8-1. Example HPGe coordinate file for the reprocessor

477536	1348828	543	624
477540	1348837	543	625
477545	1348846	543	626
477547	1348856	543	627
477549	1348866	543	628
477547	1348901	544	629

Once a suitable coordinate file is selected, the reprocessor code steps through the spectra in the selected working folder and reprocesses these spectra if there is a match between the location ID in the spectrum sample description field and the coordinate file. As an individual spectrum is being

reprocessed, the radionuclide activities determined from that spectrum are displayed as shown in Figure 8-15. The HPGe reprocessor software has many modules in common with the real-time HPGe code. If the reprocessor software detects a duplicate spectrum, the operator will be prompted (as in Figure 4-5) to indicate if it is a consecutive or non-consecutive duplicate.

Figure 8-14. Prompt to locate HPGe coordinate file to insert into analysis

8.2.1 HPGe Reprocessor File Output and Location

The HPGe reprocessor code places all rewritten spectra, summary files, and report files, in a new folder called "rev" inside the folder containing the original spectra. The files that the HPGe reprocessor generates have the same format and file names as the original files generated by the real-time HPGe code.

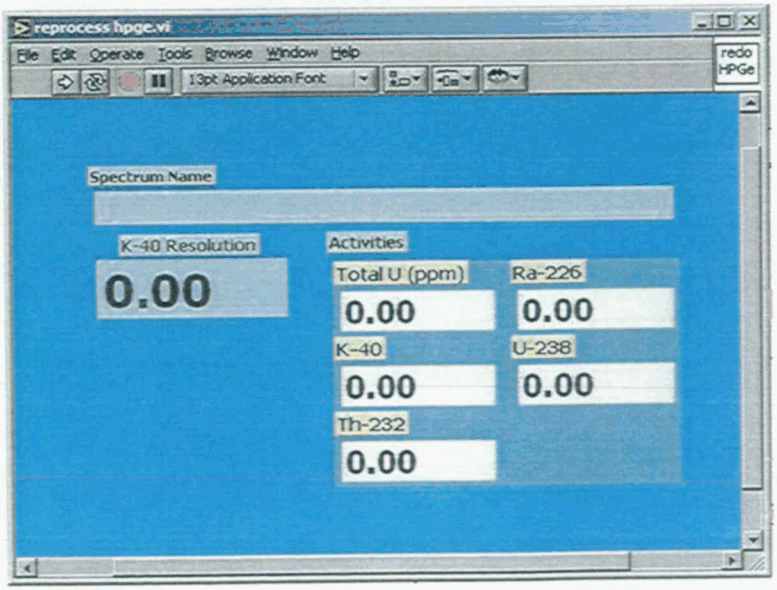

Figure 8-15. Activity display panel for the HPGe reprocessor code

8.3 Universal Worksheet Editor

During RTIMP operations, there are occasions when it is useful to create and partially complete the electronic worksheet prior to going to the field with the instruments. The worksheet editor option of the FCP master software utility (see Figure 8-1) was developed to perform this task. The universal worksheet editor uses the same software and menu system as that used by the NaI, HPGe, and EMS software. The basic operation of the worksheet editor and its file output format are described in Sections 3 and 6 of this manual. When the **Worksheet Editor** button is pushed (Figure 8-1), the software prompts the operator to select a platform as shown in Figure 8-16. Selecting the correct platform will minimize the effort required to complete the worksheet, as default values are set in accordance with the instrument selected. If the EMS platform is selected, the worksheet driver module will ask if the EMS is configured for sodium iodide or germanium operation as shown in Figure 8-17. This selection determines whether HPGe or NaI data input screens are displayed for entry of pre- and post-operation instrument QC data.

Once the appropriate platform is selected, the worksheet operation is identical to that shown in Figures 3-3 through 3-6.

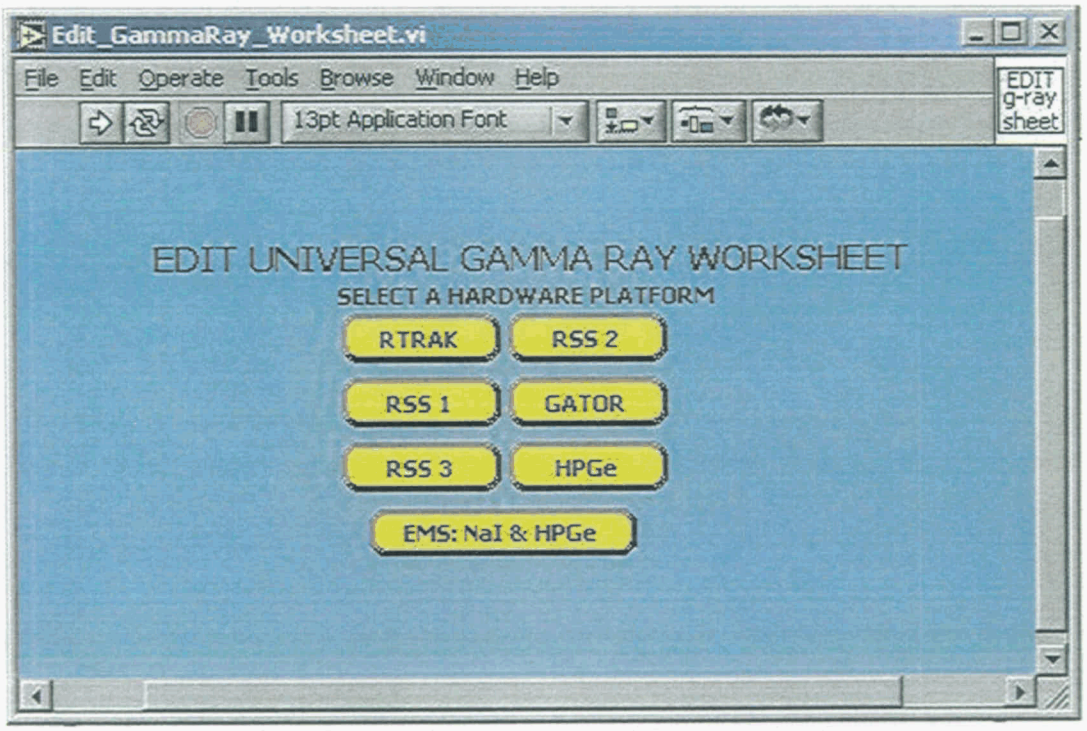

Figure 8-16. Equipment selection menu for the universal worksheet editor

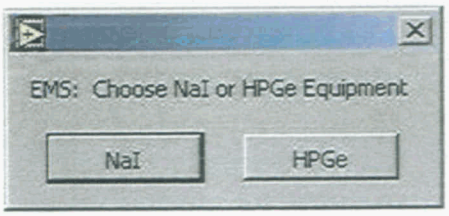

Figure 8-17. Prompt to choose NaI or HPGe equipment when using the EMS

8.4 Radon Correction

Two types of radon corrections may be applied to *in situ* Ra-226 data collected at the FCP: time-of-day or "diurnal" corrections and Lab-Field corrections (often simply called "lab" radon corrections). Older versions of this module performed both laboratory and diurnal radon correction of only HPGe data. Version 3.1 of the real time software, now corrects all HPGe and NaI Ra-226 results for soil moisture content and lab radon in the field, as part of the normal data reduction process. If diurnal radon corrections must also be applied, the radon correction module must be selected from the FCP master utility code (Figure 8-1). This module is designed to correct both HPGe and NaI Ra-226 measurement results for diurnal effects due to radon loss from the soil. Diurnal radon correction must be performed before moisture and lab-field radon corrections are applied to the raw Ra-226 results. However, because Version 3.1 of the real time software routinely applies moisture and laboratory radon corrections to both NaI and HPGe results in the field, these corrections must be removed before diurnal corrections are applied. Normally Ra-226 data from NaI measurements are not corrected for diurnal radon variations, but the radon correction module will perform this operation if desired.

The radon correction module first removes the moisture correction by solving Equation (12) for A, the raw activity prior to moisture correction. Then the laboratory radon correction is removed. Since applying the lab radon correction involves the use of second order equations to generate lab corrected Ra-226 results from raw Ra-226 activities (see Equation (23) for NaI data correction and Equation (24) for HPGe data correction) these quadratic equations must be solved to derive the uncorrected Ra-226 activity. Choosing the larger of the two roots as the appropriate the solution of the quadratic equations, the uncorrected Ra-226 activity from HPGe and NaI measurements is shown in Equations (27a) and (27b), respectively. These equations represent the Ra-226 concentration before either moisture corrections or Lab-Filed corrections have been applied. In other words, they represent the raw Ra-226 reading after moisture and Lab-Field radon corrections have been removed.

HPGe measurements: $$Ra_u = \frac{-0.98438 + \sqrt{(0.98438)^2 - 4*0.34651*(-Ra_c)}}{2*0.34651} \quad (27a)$$

NaI Measurements: $$Ra_u = \frac{-0.551 + \sqrt{(0.551)^2 - 4*0.46018*(-Ra_c)}}{2*0.46018} \quad (27b)$$

where Ra_c = the lab corrected RA-226 activity as determined by the real-time code, and

Ra_u = the desired uncorrected Ra-226 activity.

Once uncorrected Ra-226 activities have been computed using the appropriate equation from above, the diurnal radon correction can be applied by multiplying each uncorrected Ra-226 reading by the ratio of the lowest radon monitor Ra-226 activity reading of the day, to the radon monitor Ra-226 activity that occurred closest in time to the Ra-226 field reading of interest. After the diurnal radon correction has been applied, the lab correction [Equation (23) or (24)] and then the moisture correction [Equation (12)] are re-applied to arrive at Ra-226 results that have been properly corrected for diurnal radon variations, lab-filed radium differences and moisture.

When the **Radon Correction** button is pressed on the front panel of the FCP Master Utility Code (Figure 8-1), the radon correction module main panel (Figure 8-18) is displayed. Before diurnal radon corrections can commence, the operator must specify whether diurnal radon corrections are to be

performed for NaI and HPGe field data. The operator must specify the detector type because this module uses Ra-226 results in the log (summary) file, and log files for these two detector types have different formats. After designating either HPGe or NaI data, the user will be prompted to provide an output file name for the diurnally corrected data as shown in Figure 8-19.

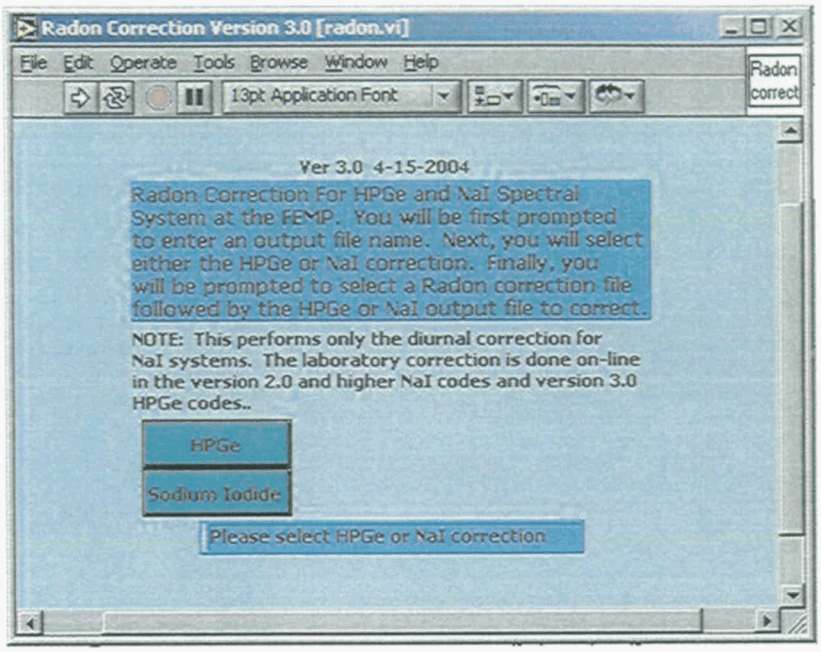

Figure 8-18. Radon correction option main front panel

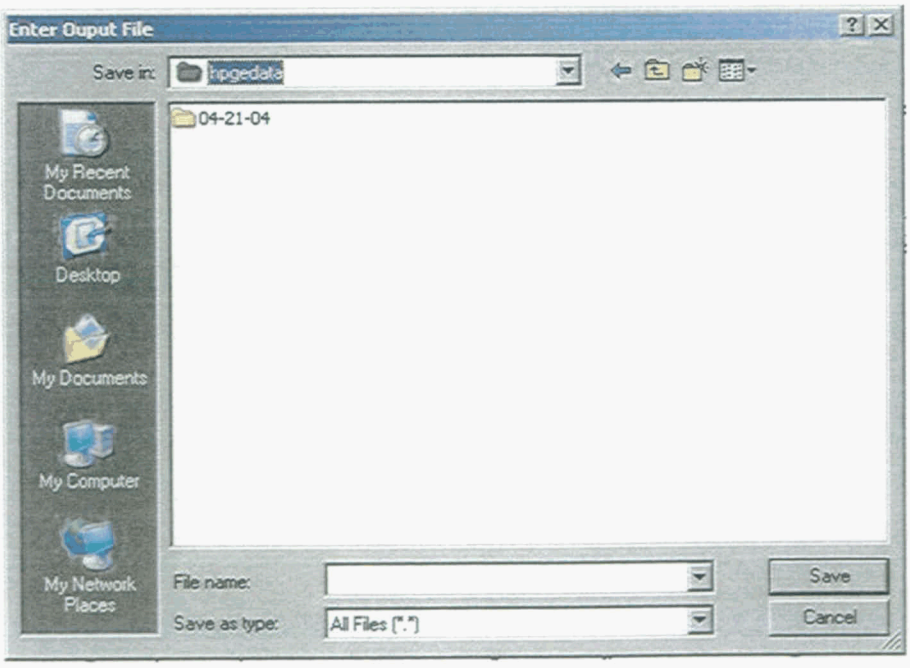

Figure 8-19. Prompt to select/create diurnally radon corrected output file

Then the user is prompted (Figure 8-20) to locate the radon monitor data file generated from analysis of the radon monitor spectral data. This file is a summary file in native EGAS format as documented in the EGAS software manual. The user is then prompted to specify the file mane and location of the summary file that contains the data to be diurnally corrected. This prompt has a slightly different appearance, depending on whether NaI data (Figure 8-21) or HPGe data (Figure 8-22) was selected for correction.

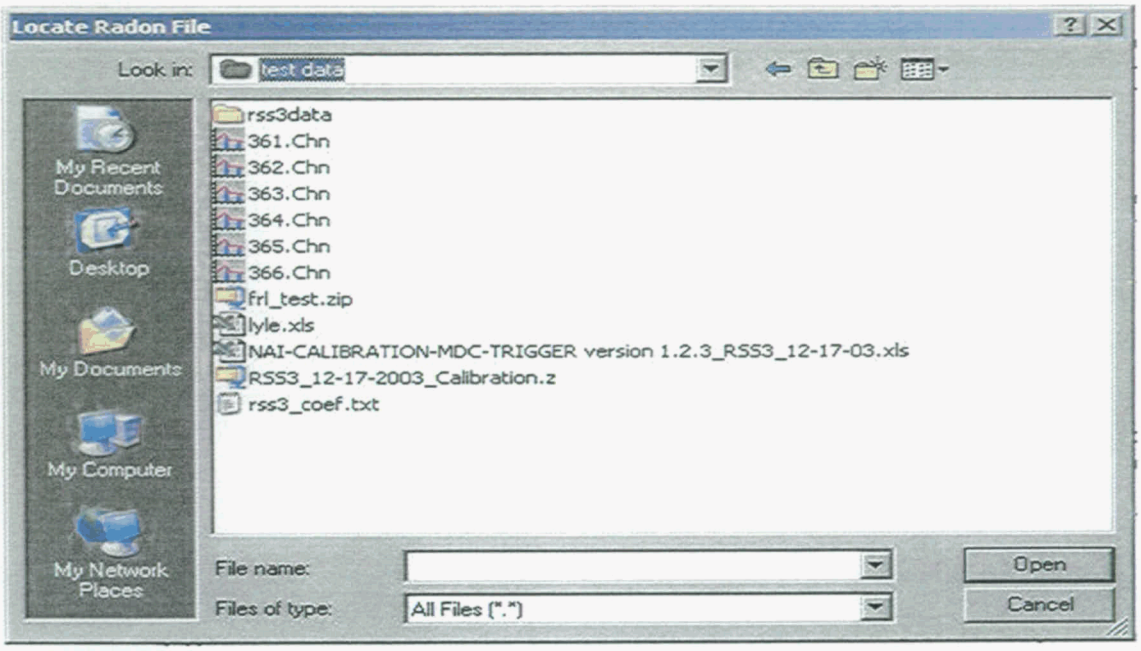

Figure 8-20. Prompt to locate radon monitor output data file

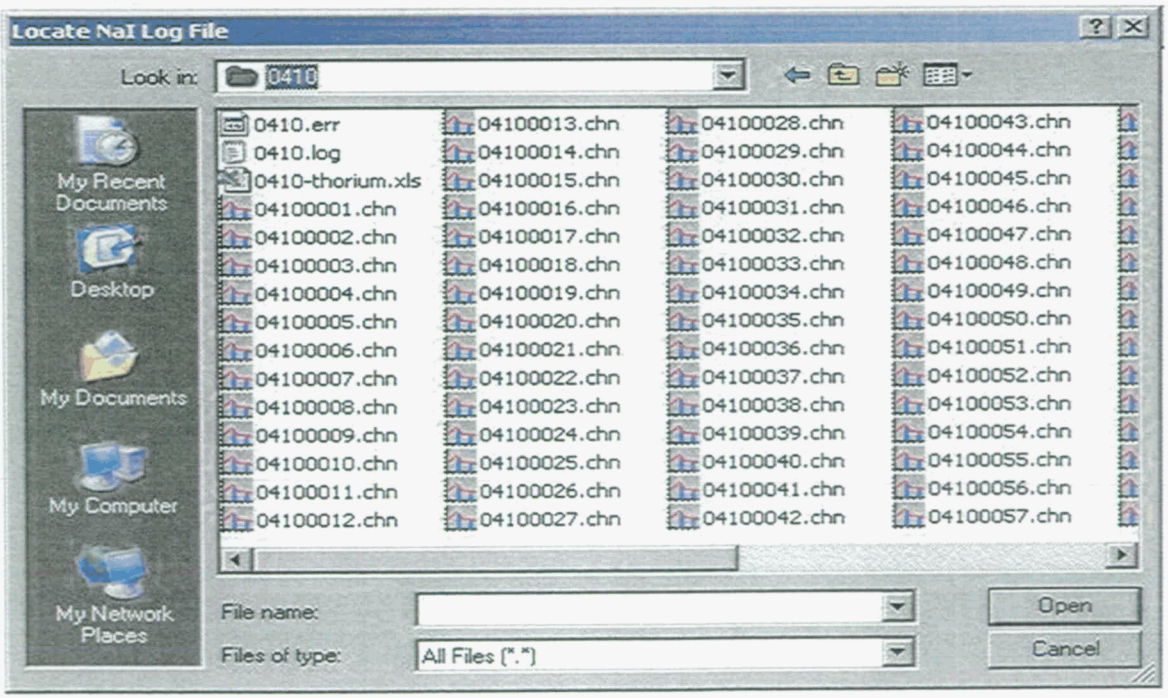

Figure 8-21. Prompt to locate the NaI log file that required diurnal radon correction

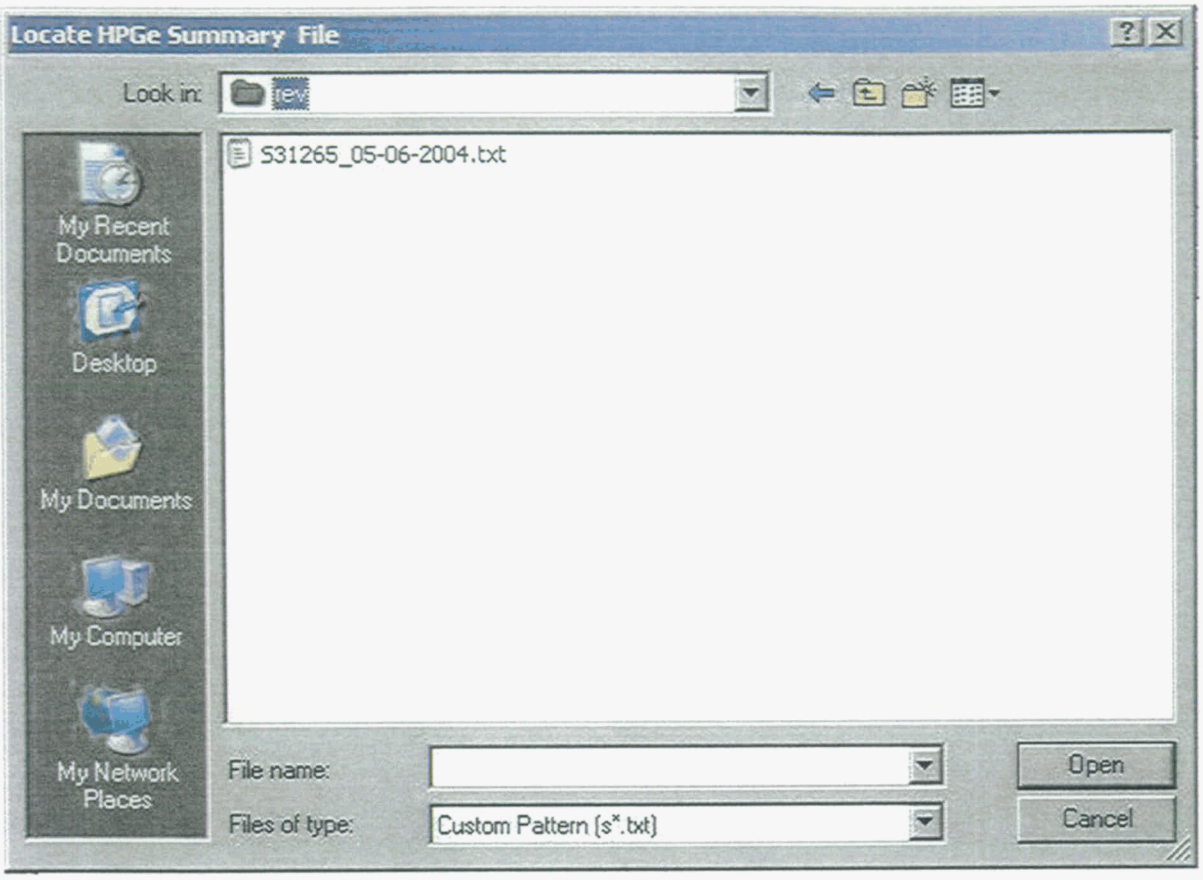

Figure 8-22. Prompt to locate the HPGe summary file that requires diurnal correction

HPGe summary files can occur in either native EGAS format, or real-time HPGe format. The diurnal correction software is able to handle either type of HPGe summary file. Figure 8-23 shows the prompt issued by the radon correction software asking the operator to select an HPGe summary file format.

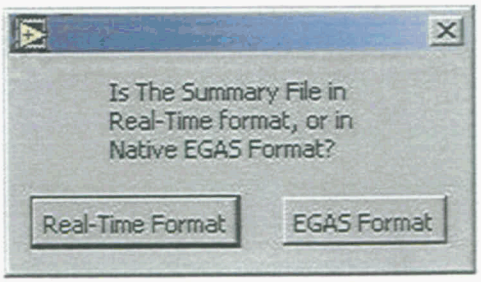

Figure 8-23. Prompt to determine type of HPGe summary file

8.5 EGAS Reformatter Module

The EGAS reformatter module was created for the Version 3 software suite to streamline the processing of data that were analyzed by the full version EGAS software package. For various reasons, the simplified version of EGAS incorporated into the real-time HPGe software may fail to properly analyze some unusual spectra that are collected in the field. In such cases, the full version of EGAS, which includes many more analysis options, is required to analyze the abnormal HPGe spectra. The EGAS reformatter module reads native EGAS summary file and converts it to a file having the real-time HPGe format, like that described in Table 6-7. In addition to writing the summary file into the standard RTIMP format, the reformatter module tests the file contents against various criteria and generates all the QA and duplicate codes required by the RTIMP database.

When the **EGAS Summary File Reformatter** (Figure 8-1) button is pressed, the module prompts the operator to locate the summary file to be reformatted as shown in Figure 8-24. Once the summary file is selected, the code reads the summary file and expects to find a corresponding report file from which to extract QA and duplicate code information. If the summary file selected does not contain analysis results from duplicate measurements, the EGAS reformatter code runs to completion without user intervention. If a duplicate analysis result is encountered, then the code proceeds through the same sequence as that described in Section 4.2 of this manual pertaining to duplicate measurement processing.

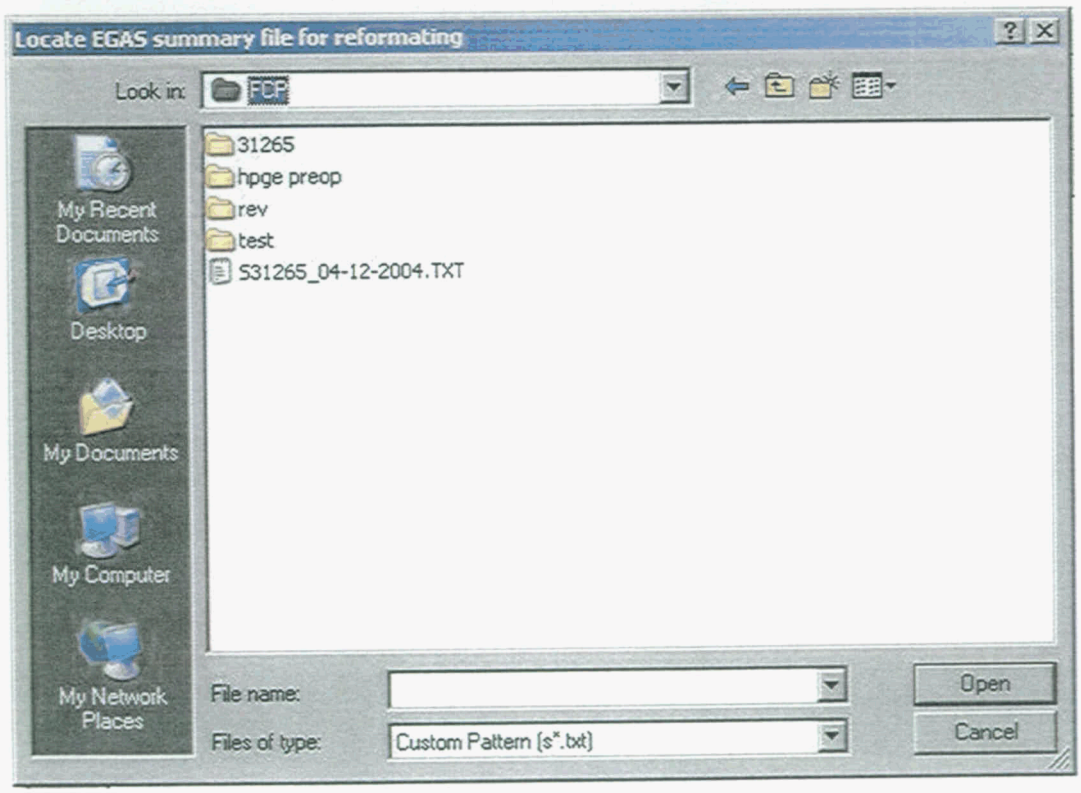

Figure 8-24. Prompt to locate EGAS summary file for reformatting

At completion of the reformatting operation, the code renames the old (native EGAS) summary file by adding a "_old" character string to the end of the suffix on the file name, and saxes the reformatted file under the original EGAS output summary file name. This preserves the original EGAS summary file for later retrieval if desired.

8.6 QA Code Checker Module

The QA Checker provides a way to visually inspect the QA and duplicate codes generated by the HPGe real-time software (EMS and HPGe), the HPGe reprocessor module, and the EGAS reformatter module. This software is new in Version 3.1. This module does not operate on NaI data. It does not perform any calculations, or modify any of the report or summary files. It is simply a visual tool to look at the QA and duplicate codes quickly without having to import the summary file into a spreadsheet. The front panel of the QA checker is shown in Figure 8-25.

When the **QA Code Checker** button on the front panel of the FCP Master Utility Code, (Figure 8-1) is pressed, the software prompts the user to locate an HPGe summary file. This prompt is similar in appearance to that shown in Figure 8-24. The summary file is read into memory and the structure shown in Figure 8-25 is filled in with the appropriate information. The array control index located to the left of the first line of data can be used to scroll through the data in the event that there are more data lines in the summary file than can be displayed on the screen at one time.

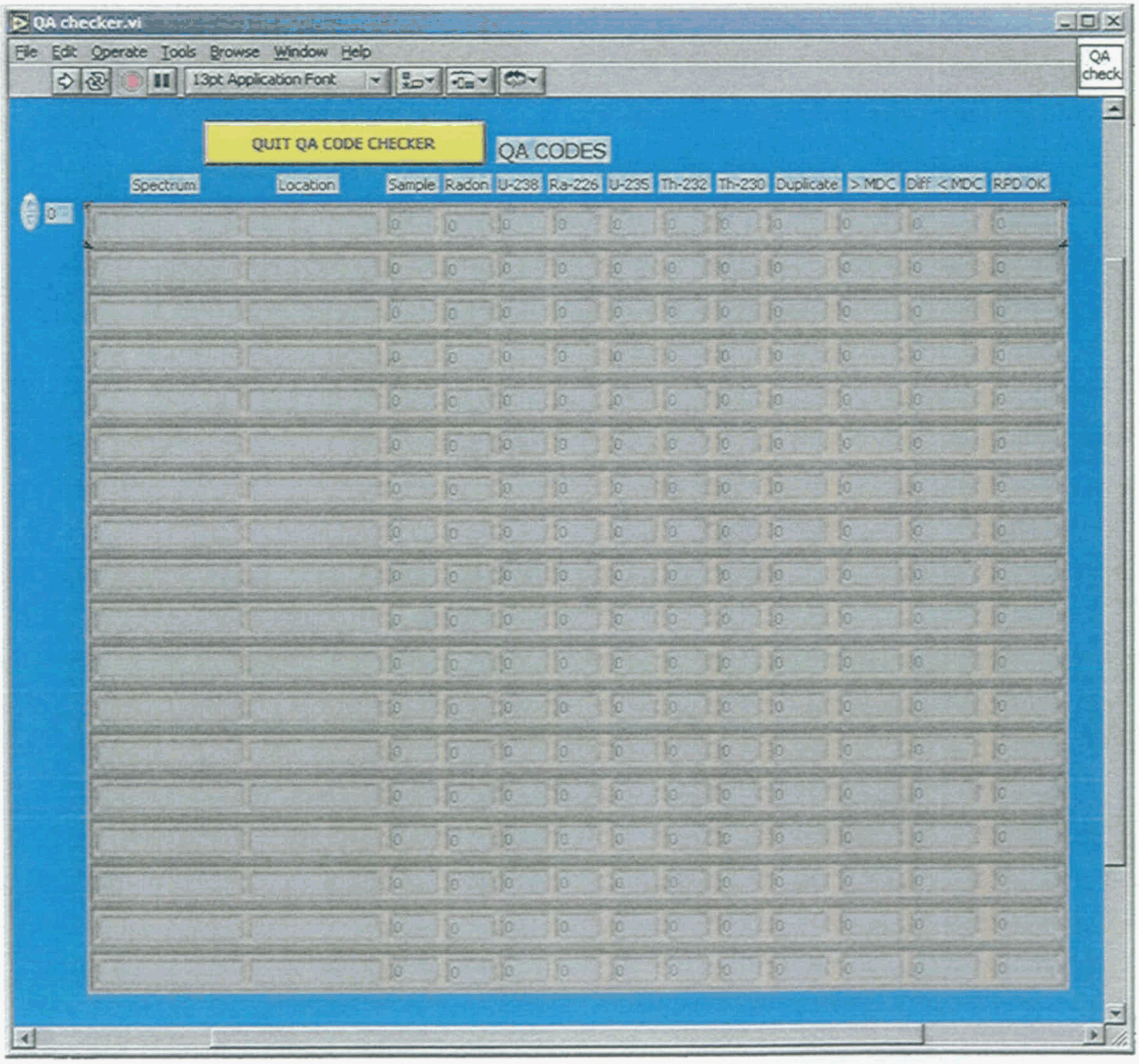

Figure 8-25. QA code checker front panel

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APPENDIX A

EMS HARDWARE QUICK STARTUP GUIDE

EMS Hardware Quick Startup Guide

GPS System Setup

1. **Prepare GPS unit for Survey**. The entire GPS system should be readied per Fernald operating procedures. This includes establishing a base station link for real-time differential correction, and any other preparation required for the GPS unit.

2. **Install the GPS hardware onto the EMS**. Install the GPS and radio link antennae on the EMS. If necessary, remove the ArcSecond receivers and place them in their proper storage cases.

3. **Attach mechanical sections and detector hardware to the EMS**. Configure the EMS as desired and attach/verify all cable connections.

4. **Turn on EMS, FCP control van computers, and excavator cab computers**. Apply power to the computers and verify that the wireless network is operational. It may take up to two minutes for the operating system to establish shared disk access between the EMS, the van computer and the cab computer. Connectivity can be verified by pressing the Network Neighborhood icon on the desktop of the van computer. The van, cab and EMS computers should be listed.

5. **Turn on High Voltage to the Detector**. Using GammaVision, turn on the high voltage on the EMS to the desired setting from the FCP control van.

6. **Launch FCP control van EMS software**. Start the EMS Van control software located on the desktop of the van computer. This will initiate the van control software, which is a menu driven program.

7. **Configure the EMS**. Configure the EMS for point/look, moving scan, detector presets.

8. **Enter worksheet data**. Enter appropriate worksheet data. This will initiate the survey control front panel once complete.

9. **Collect data**. Data can be collected with the EMS by pressing the start survey button.

ArcSecond System Setup

1. **Check the Compaq Aero palm-top computer for availability of the ArcSurvey program**. The program will be lost if the Aero does not have continuous power. Is the ArcSurvey program available and functional on the Aero? Yes, go to step 4. No, go to step 2.

2. **Install ArcSurvey program**. Place the Aero in the cradle and allow the Aero to automatically synchronize with the desktop the cradle is connected to. Insert the ArcSurvey installation floppy disk and run the ArcSurvey installation program (ArcsurveyInstall.exe). Once the installation is complete, configure the ArcSurvey program for the proper transmitters. This is done in ***Setup/Settings/Tx*** submenu. Press the ***Tx*** button from the Settings menu to change the transmitter number. The correct transmitter files are ***V_227.asd*** and ***V_232.asd***.

3. **Configure the tool setup**. Go to the ***Setup/Settings*** menu and press the ***Tool*** button. The ArcSurvey program will present a submenu describing the various components of the tool. For example, the tool comes with long, medium, and short extensions and two different types of tips. The software must reflect the tool configuration that will be used in the field. This step should be re-checked prior to each calibration and survey activity. The position system is now ready to go to the field.

4. **Select Vulcan transmitter locations**. Carefully select transmitter locations to provide the best line-of-sight coverage for the given survey. Consideration should be given to where the excavator will be during the survey. Transmitters should not be located near a line drawn between two of the calibration points.

5. **Turn on Aero and Start the ArcSurvey Program**. Make sure all connections to the Aero and the Position Control Engine are correct. Re-check the tool configuration. The software must reflect the tool configuration that will be used in the field.

6. **Adjust the ArcSecond Range Setting**. In the ***Setup/Range*** menu, adjust the range setting so that all sensor/transmitter combinations are functional. This is indicated by the presence of four blinking dots on the ***Range*** menu.

7. **Calibrate the ArcSecond System**. There are two types of calibrations commonly used. A resection calibration is used to tie into an existing coordinate system. In a quick calibration, the ArcSecond system will generate its own coordinate system. The resection calibration procedure requires a minimum of four known points in the survey area. If the survey will be tied to the Ohio State Plane system, these points should be obtained from a hand-held GPS or a total station survey. Go to the ***Range/Calibration*** menu and select either the ***Quick*** or the ***Resection*** calibration method. Follow the menu directions to calibrate the system. Details are provided on Pages 9 and 10 of the Vulcan User's Manual.

8. **Install Arcsecond Receivers**. The two Arcsecond receivers must be attached to the EMS and connected with the proper cables. If necessary, remove the GPS antenna and radio link antenna.

9. **Attach mechanical sections and detector hardware to the EMS**. Configure the EMS as desired and attach/verify all cable connections.

10. **Turn on EMS, FCP control van computers, and excavator cab computers**. Verify that the wireless network is operational. It will take up to two minutes for the operating system to establish shared disk access between the EMS, the van computer and the cab computer. Connectivity can be verified by pressing the Network Neighborhood icon on the desktop of the van computer. The van, cab and EMS computers should be listed.

11. **Transfer the ArcSecond Calibration data from the Aero to the EMS computer**. Place the Aero in its docking cradle. This should initiate an ActiveSync session on the van computer. Highlight and copy the ***V_227.asd*** and ***V_232.asd*** files in the ***Arcsurvey/Txs*** folder on the Aero. Open an explorer session on the van computer and go to the ***c:\arcsecond*** folder on the EMS computer. Paste the transmitter files into this folder.

12. **Turn on High Voltage to the Detector**. Using GammaVision, turn on the high voltage on the EMS to the desired setting from the FCP control van.

13. **Launch FCP control van EMS software**. Start the EMS Van control software located on the desktop of the van computer. This will initiate the van control software, which is a menu driven program.

14. **Configure the EMS**. Configure the EMS for point/look, moving scan, detector presets.

15. **Enter worksheet data**. Enter appropriate worksheet data. This will initiate the survey control front panel once complete.

16. **Collect data**. Data can be collected with the EMS by pressing the start survey button.