

In-flight, online processing and mapping of airborne gamma spectrometry data

Benno Bucher, Paul Scherrer Institute, CH-5223 Villigen-PSI, e-mail: benno.bucher@psi.ch, phone: +41 56 310 23 38, fax: +41 56 310 23 09

Ladislav Rybach, Institute of Geophysics, ETH Hoenggerberg, CH-8093 Zurich

Georg Schwarz, Swiss Federal Nuclear Safety Inspectorate, CH-5223 Villigen-HSK.

Abstract

Airborne gamma spectrometry is a technique especially useful for environmental monitoring and emergency preparedness. Because time is a critical factor in emergency response a fast data processing and mapping software is needed, which also supports online monitoring and data processing features. Therefore a new online data processing and mapping software was developed, which also displays successfully the gamma spectra, the ground activity, and the topographical data. The software was successfully tested during various survey flights.

Classification Codes (PACS-1996): 89.60.-k, 93.85.+q, 29.30.-h, 29.85.+c

Keywords: online, airborne, gamma spectrometry, processing, mapping

1 Introduction

Airborne gamma spectrometry in Switzerland began in 1986 as a project of the Swiss Geophysical Commission. Within this project aimed at geological mapping a special data processing method and software was developed [1]. In 1994 the airborne gamma spectrometry was integrated in the National Emergency Preparedness Organization. The Swiss Army handles measurement equipment and data processing in emergency situations. Authorities and decision makers need radiation data as quick as possible. E.g. when searching for a lost radioactive source, continuous monitoring and display of the measured data is critical. Operating the measurement equipment and the data processing software must be simplified to allow its use by non specially trained persons. The method presented allows the measurements to be monitored and evaluated during the flight; the radiation maps are displayed in real time.

2 Goals

The new software should be user friendly and have up-to-date technology incorporated. It has to provide reliable of airborne measurement results in a short time or even online. The monitor tool should display the spectral information and the processed data for at least of the 60 last measurement points. In this way differences in the measured data can be easily recognized. To fix the results in space and to relate them to other spatial data the measured data must be mapped. To help the pilots of the measuring aircraft a navigation tool has to be implemented which shows the flight lines or route points and the deviation of the current position from the predetermined survey line. For post-processing purpose the software needs to have a second running mode. In the online mode the raw data are taken from the data

acquisition system, in the offline mode the raw data are read from a data storage file. Further on the software must enable to monitor the raw data as well as the processed data. For data exchange purposes the data export in different data formats must be possible. Finally software handling mistakes or errors in the data should be recognized and corrected.

The ultimate goal is the visualisation of flight tracks, spectrometer data, processed data, and of the generated maps (ground activity of radioisotopes, dose rate) during the flight in real time.

3 Realisation

3.1 General Concept of the Software

The concept of the software is derived from a system, which was developed at the Swedish Radiation Protection Institute SSI [2]. Discussions and the cooperation with SSI [3] led to the following concept (see also Figure 1): The core of the software consists of three parts:

- *main container*. It contains the other parts of the software and is responsible for the user interaction and steering of the software by menus (see Figure 2).
- *handling of the raw data*: It manages the handling of the raw data and the data processing (depending on the acquisition system).
- *data display*. It displays the data in different manners which help the user to monitor the data and which help the pilots to navigate.

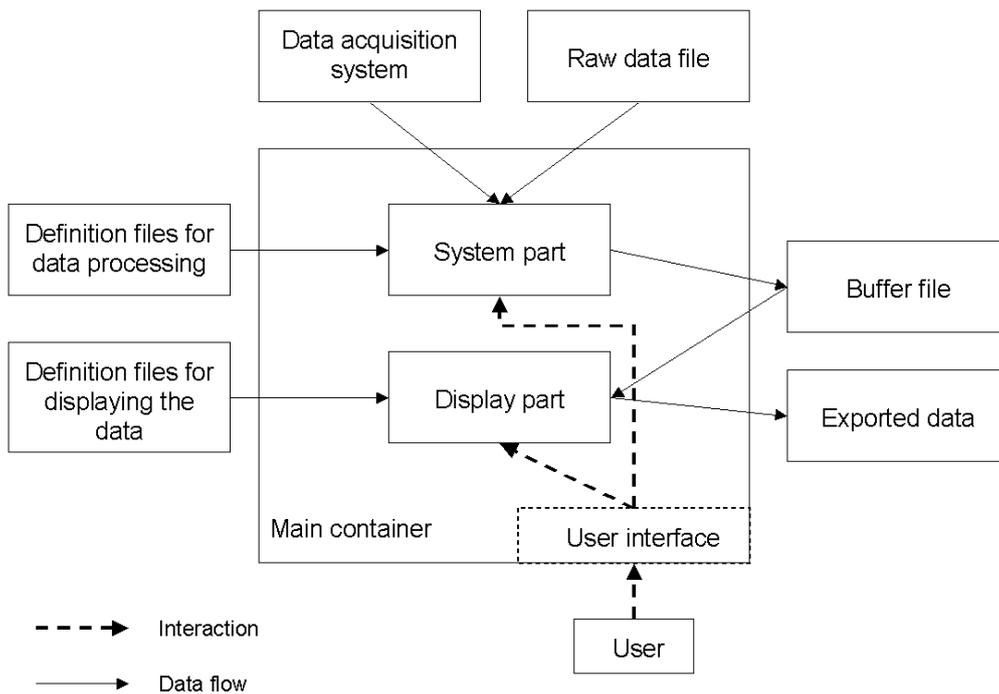


Figure 1: Schematic view of the software concept.

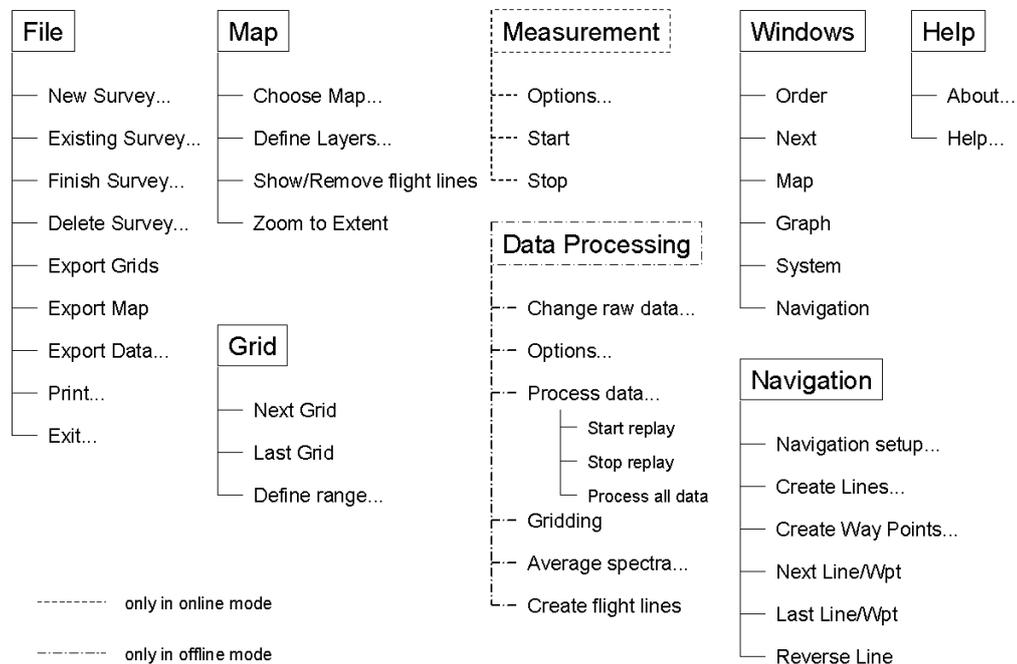


Figure 2: Menu structure of the new software. The boxes correspond to the main menu.

The configuration of the different software parts is driven by definition files. They are plain text files, which can be easily handled and changed by an ASCII editor.

As a main functionality, data export routines were implemented to compile the results in reports and also to exchange data with other software or other users.

3.2 Data processing in real time

Before raw data are processed, the quality of the collected gamma spectra is analysed. If the peaks lie outside of a defined energy range or the energy resolution does not fulfill the requirements an alert is generated and displayed on the screen.

For the data processing the well-known windows method is used. Regarding the spectra evaluation background is subtracted, stripping and altitude corrections are applied. The radiation background comes from the aircraft and the other equipment and from the cosmic radiation. Also the contributions from higher-energy gamma lines to the analysed region of interest are stripped. Then the windows (spectra regions) are normalized to the defined flight altitude 100 m above ground. For that purpose radar is used to measure the altitude. If there is a digital terrain model available a ground clearance can be calculated using the X, Y and Z coordinates of the aircraft position (from GPS) and the digital terrain model. For surveys in areas with rough topography the topographical correction described in [4] can also be applied in real time. After all the corrections made the net count rates of the windows for ^{40}K , ^{238}U , ^{232}Th and ^{137}Cs are converted to ground activities using calibration factors.

Details regarding the online software and the dose rate determination at ground level are given in [5].

3.3 Tools for data monitoring

Within the software, which is running on a laptop computer, different tools are available for the monitoring of the measured raw data and of the processed data. In the so-called “system” visualizer the raw data received from the data acquisition system are displayed and tabulated. The purpose of this tool is to monitor the data flow from the data acquisition unit to the data processing unit.

Other tools show the flight line with the actual aircraft position, the „waterfall spectra“ (see below), radioisotope and dose rate maps.

In Figure 3 an example of the “graph” visualizer is given. There the raw spectral data and also the processed data are displayed. On the top left side of Figure 3 a so-called waterfall display method is used to show around 200 spectra at the same time. The vertical axis corresponds to time along a flight line. Each horizontal line corresponds to one spectrum (gamma energy increases to the right). From left to right the counts for each channel are displayed as colors. The color depends on the number of counts and is increasing from black over blue, green, yellow, red to white. There is also the possibility to switch the color scale between linear, square root and logarithmic. Usually a square root scale is applied. In this way also small changes in the spectra can be very well distinguished. As it can be seen different radioactive sources can be easily recognized and identified with the waterfall spectra display. On the bottom left of the “graph” visualizer the current spectrum is displayed as pulse high distribution. On the right of Figure 3 two profiles of the processed data are shown, dose-rate on the left, radar altitude on the right. The displayed value in the profile can be chosen from all values, which are calculated during the data processing. The display is updated with each processed data point. The scale for each part of the “graph” can be set individually.

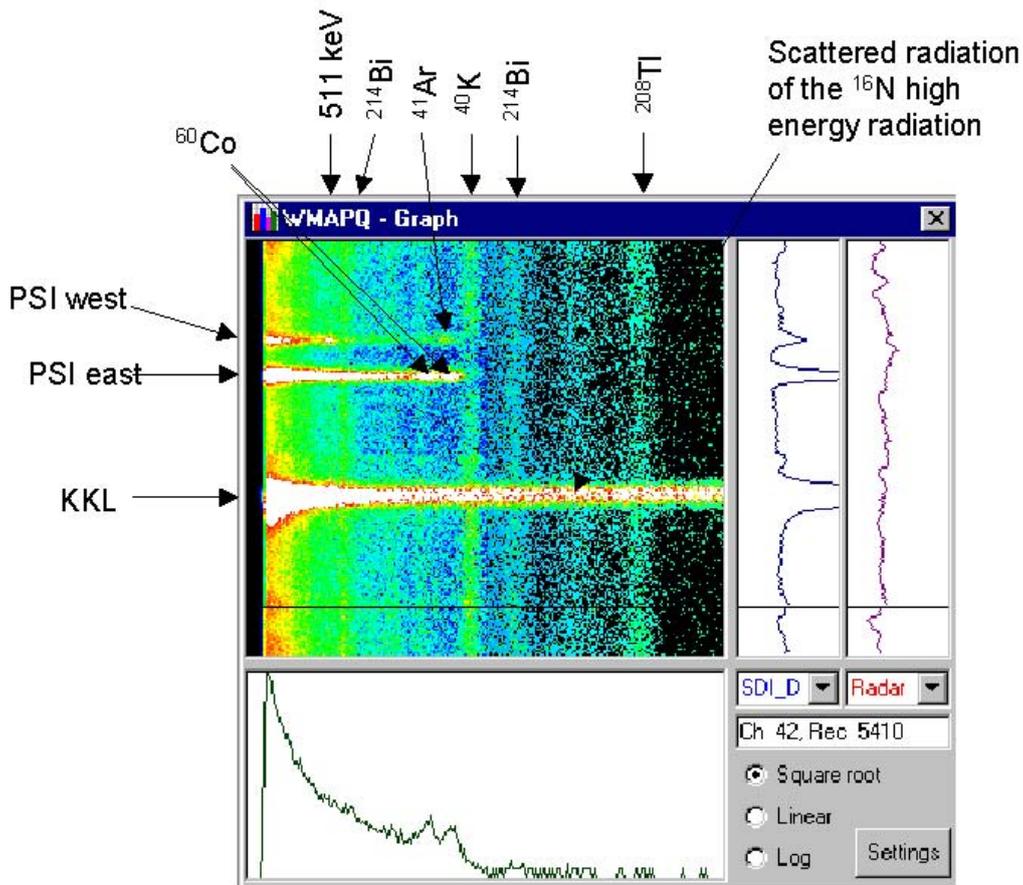


Figure 3: Different anomalies in the survey area of the two nuclear power plants Beznau (KKB) and Leibstadt (KKL) and of the research facility Paul Scherrer Institute (PSI). ^{40}K , ^{214}Bi and ^{208}Tl are from natural radiation; the ^{60}Co activity originates from the radioactive waste storage facility at PSI east, the ^{16}N radiation from KKL (which has a boiling-water reactor), and the 511 keV annihilation radiation as well as the ^{41}Ar activity from the ion accelerator at PSI west. For details see text.

3.4 Real time mapping

Finally the processed data are mapped and displayed together with topographical data. To display the map the developing tool MapObjects 2.2 of the Geographical Information System (GIS) software provider ESRI was used. This tool enables to

combine various measured data sets like dose rates with basic data like the topography.

For mapping the survey area is covered with a grid of quadratic cells. In the online mode this grid is automatically growing with the size of the survey area. That means that the grid is sized up as soon as a measurement point lies outside of the current grid perimeter. The size of the grid cells can be set by the operator and is defined before the start of the flight.. Usually the half of the line spacing distance is taken as the cell size.

Upon flight start the grids for the chosen processed data are initialized. So for each thematic map an array for the values and another array for the number of values in a cell are created. During the flight the processed values are filled into those arrays, summed up in each cell, and the number of values per cell is counted.

At one time only one grid can be displayed, so just the currently chosen grid is shown in the map. Because it is much too time consuming to recalculate the whole grid each time and a new value influences just the nearest neighborhood, only a small part of the grid is recalculated and displayed. For the interpolation of empty cells in the grid a simple method described in [6] was implemented. After the interpolation the grid is transformed to a colored bitmap using a user-defined scale and is stored in a file. The colors are going from blue over green and yellow to red. To place the created bitmap at the right position in the map a so-called world file is created. This file contains the information about the position of the lower left corner and the size of a pixel. Now the grid part is displayed in the map, covering earlier parts of the bitmap. This small part of the grid is moving with the current position of the aircraft and the map is continuously updated. In case of upsizing the grid, the full grid is recalculated and transformed to a colored bitmap. That bitmap lies under the moving part of the grid.

The operator can choose which gridded value is being displayed in the map. The color bar (scale) of the grid can also be changed during the flight.

3.5 Navigation tool

With the new software also a navigation tool is available. It allows to create the flight lines or the route points and to store them in a file. If such a file is chosen in the navigation setup, a line or route point can be activated. For each new aircraft position as determined by the GPS receiver of the measuring system the distance to the planned line or route point is calculated and graphically displayed. So the pilot can keep easier to the track. At the same time the planned lines are also drawn in the map; the chosen line and its end points are marked.

4 First experiences

In the past three years the online software was brought to action during several airborne surveys. In surveying the environs of Swiss nuclear installation sites the measurements could be monitored conveniently and easily. Anomalies in the spectra can be recognized quickly with the tools in the “graph” visualizer. So a first analysis of the data is immediately possible. In a survey around the two nuclear power plants Beznau and Leibstadt and the research facility Paul Scherrer Institute several anomalies could be recognized and identified, which are caused by man-made radiation. At the nuclear power plant Leibstadt (KKL, which has a boiling water reactor) the radiation of the activation product ^{16}N could clearly be seen (Figure 3). Because of the high-energy gamma lines of ^{16}N scattered radiation was measured over the whole spectra. At the research centre Paul Scherrer Institute, where the Swiss Federal Intermediate Storage Facility for radioactive waste is also located (PSI east) the radiation of ^{60}Co could be detected and identified during the flight. Finally

over the western part of the Paul Scherrer Institute (PSI west) where a high-energy proton accelerator is running, positron annihilation radiation and low activities of ^{41}Ar were registered (see Figure 3).

In an exercise where the scenario of searching for a lost radioactive source was trained the advantage of the new software could be very well demonstrated. In earlier years during the flight only the spectrometer display gave some information about the raw counts for the last 30 seconds. So it was very difficult to see any difference between natural fluctuations in the radiation field and the signal of a weak source on the ground. With the new software in the online mode the raw data are processed during the flight and the results are displayed on the screen. Figure 4 displays the visualizers “graph” and “map” (the features of “graph” are described above and in Figure 3). The “map” visualizer (top part of Figure 4) shows the flight lines along with the processed data, in this case the MMGC ratio. MMGC is the ratio of the low energy to the high energy part of the gamma spectrum; it emphasizes the man-made radiation present [1]. Mapping the MMGC ratio and watching the “graph” visualizer makes it much easier to find and to identify a source. Figure 4 shows also the ground radiation (DKR_T), top right in “graph”. So a 190 MBq ^{60}Co source could quickly be located and identified during an exercise flight.

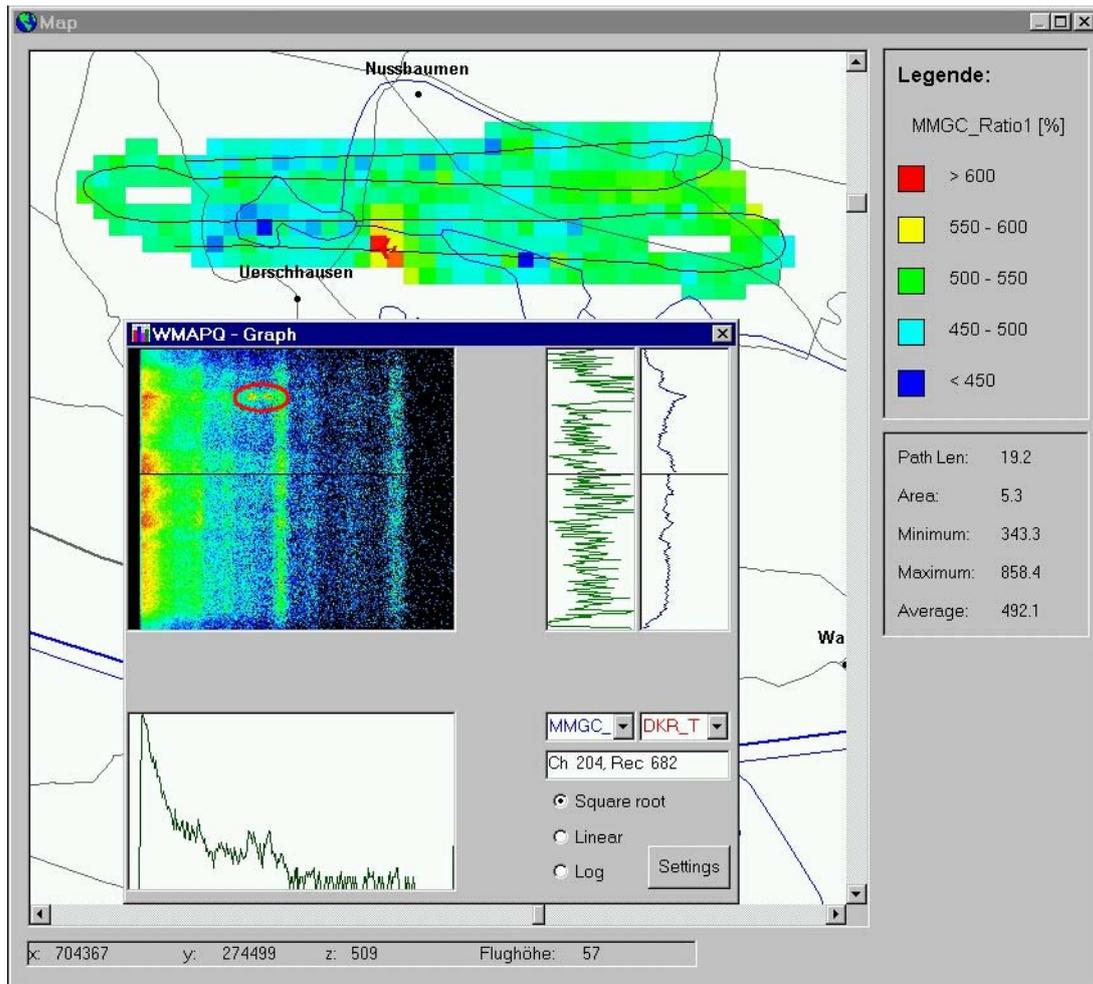


Figure 4: The view of the “map” and the “graph” visualizers during the online processing of a radioactive source search survey. In the “graph” the spectrum is shown where the ^{60}Co source could be identified (red ellipse on the waterfall spectrum) and localized (red zones on the map) during the flight. For details see text.

5 Conclusions

The new software is able to display and monitor the raw and the processed measurement data including radiation maps, during the flights allowing the recognition, localisation and identification of anomalies online.

Also in the offline mode results are available in less than five minutes. Because there is just one step to process and map all data the data processing is straightforward.

In large forested areas and mountainous regions visual navigation with hard copies of maps is very difficult. With the navigation tool integrated in the new software it is now much easier and considerable flight time can be saved.

The online system was successfully tested and implemented since the 2000 annual survey of Swiss nuclear power plants [7].

Because the measurement and navigational part of the software is separated from the display part, the software can be quickly adapted to other airborne gamma spectrometry data acquisition systems. E.g. it was used together with the Swedish equipment in the Barents Rescue 2001 LIVEX Exercise [3]. A further deployment of the Swiss system took place during the International RESUME2 Exercise in 2002 within the EU project ECCOMAGS [8].

6 Acknowledgments

We thank the Swiss Federal Nuclear Safety Inspectorate and the Swiss National Operations Centre for continued support.

7 References

- [1] Schwarz, G., 1991: Methodische Entwicklungen zur Aerogammaspektrometrie. Beiträge zur Geologie der Schweiz, Geophysik Nr. 23, Kümmerly & Frey AG, Geographischer Verlag, Bern.
- [2] Mellander, H., 2000: Real Time Software for Survey Planning and Support – a Game or a Tool? In: Recent Applications and Developments in Mobile and Airborne Gamma Spectrometry. Proceedings of the RADMAGS Symposium, 15-18 June 1998, University of Glasgow, Scotland, ISBN 0 85261 685 6.
- [3] Ulvsand, Th., Finck, R. R., Lauritzen, B., 2002: NKS/SRV Seminar on Barents Rescue 2001 LIVEX Gamma Search Cell. Proceedings. NKS-54, ISBN 87-7893-108-8.
- [4] Schwarz, G., Klingelé, E., Rybach, L. (1992): How to Handle Rugged Topography in Airborne Gamma Spectrometry. First Break, 10, p. 11-17.
- [5] Bucher, B., 2001: Methodische Weiterentwicklungen in der Aeroradiometrie. PhD Thesis Nr. 13973, ETH Zurich.
- [6] Green, A. A. 1987: Leveling airborne gamma-radiation data using between-channel correlation information. Geophysics, 52, p. 1557-1562.
- [7] Bucher, B., Rybach, L., Schwarz, G., Bärlocher, Chr., 2001: Aeroradiometrische Messungen im Rahmen der Übung ARM00. Bericht für das Jahr 2000 zuhanden der Fachgruppe Aeroradiometrie (FAR). Internal Report, Institute of Geophysics, ETH, Zurich.
- [8] D.W.C. Sanderson, A.J. Cresswell, J.J. Lang (eds.), 2003: An International Comparison of Airborne and Ground Based Gamma Spectrometry, University of Glasgow Press