RTRAK - A FIRST GENERATION AUTOMATED CONSTRUCTION VEHICLE

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ABSTRACT

RTRAK is a mobile, computer based, gamma scanning and radiation mapping system developed by Chem-Nuclear Systems and MK-Ferguson Company for use on the Uranium Mill Tailings Remedial Action Project.

Verification of large land areas contaminated with uranium mill tailings for compliance with U.S. EPA standards for 226-Ra in soil is an expensive and labor intensive process using traditional methods. The EPA criteria require measurement of 226-Ra concentrations over discrete 100 square meter (centihectare) land areas. In some areas of the west and southwest, windblown contaminants cover many thousands of centihectares. In the UMTRA project, one site alone will require verification of over 40,000 centihectares. A computer based, mobile gamma scanning vehicle has been developed that can correlate in-situ gama measurements with 226-Ra concentrations, associate that data with microwave generated x, y grid locations, and plot relative radionuclides concentrations on the computer display as it is collected. The system is capable of marking areas that do not meet the appropriate criteria to expedite further cleanup. The data is stored on magnetic media for archival or analysis at a later date to provide a variety of reports.

I. RTRAK - A Computerized Radiation Tracking System

The Albuquerque Operations Office of the Department of Energy (APO) is responsible for the Uranium Mill Tailings Remedial Action Project (UMTRA). The UMTRA Project entails the remediation of large land areas contaminated with uranium mill tailings, to meet U.S.E.P.A., standards for residual Radium 226 (Ra-226) contamination. The APO's remedial action contractor team, MK-Ferguson Company and Chem-Nuclear Systems, Inc., have jointly developed a computerized, radiation scanning vehicle (RTRAK) to assist in this effort by providing characterization, excavation control, and verification surveys of large land areas. RTRAK is not a new concept; in the past several organizations have developed sophisticated, mechanized radiation measurement systems to aid in large scale investigations. At the Nevada test site, EG&G has been using both aircraft and surface vehicles equipped with computerized radiation scanning/quantification systems for years to support test activities and environmental monitoring. Oak Ridge National Laboratories utilizes a gamma scanning vehicle to locate contaminated properties for further investigation in both the Formerly Utilized Sites Remedial Action Project (FUSRAP) and the UMTRA Project. Recently, Hanford scientists developed a beta/gamma scanning vehicle to facilitate investigations at that site. RTRAK represents a marriage of many of the attributes found in all of those devices, but not fully incorporated in any one of them. In addition, RTRAK incorporates certain unique features, such as a detector mounting system which maintains a constant counting geometry, real-time mapping of survey data, and computer controlled "hot spot" marking during the survey.

The design criteria for RTRAK called for an off-road or "all terrain" vehicle with a cab housing two operators; a driver who is also responsible for maintenance, and a health physics technician whose responsibilities include operation of the data acquisition system, guidance of the survey, reporting to the local site management or project office, and electronic/electrical repair. As much as possible, all instrumentation is "off-the-shelf" to reduce down time for repair or replacement. If a ruggedized piece of equipment was readily available, it was used, but if such an item required extensive lead time item, the standard item was used, spares purchased, and protective features built in (if possible). It is not economically practical to allow RTRAK to be idle for an extended period of time waiting for replacement equipment with an earth moving contractor on standby waiting for RTRAK to provide essential data. In the UMTRA Project, those costs can be several tens of thousands of dollars per day.

RTRAK can be broken down into four major systems:

1. The mechanical system, which is the tractor, tractor cab, and the detector mountings.

2. The electrical system, which is the generator and the 120v. AC distribution system.

3. The electronics system, which includes the detectors, amplifiers, detector high voltage, ADC's, computer, and positioning systems, and,

4. The computer software.

For the purpose of this presentation, only a brief description of the first two systems will be provided and the last two systems will be described in detail.

II. Mechanical System

The RTRAK vehicle is a four wheel drive farm tractor equipped with a second hydraulic pump to assure an adequate capacity for detector manipulation. The engine size was specified to provide an adequate frame size and there is more than sufficient power for RTRAK's present requirements. The cab was custom built at MK-Ferguson's fabrication facility in Boise, Idaho, to provide an adequate area for the operators and the electronics. The detector mounting system, designed and built by MK-Ferguson, supports four detectors in a uniform counting geometry by allowing each detector to individually traverse most surface irregularities without effecting the other detectors or the detector to surface relationship. The detectors may also be articulated in pairs to allow surveys of ditches and hillsides. There is a lead collimator around each detector which effectively limits the detector field of view to a two foot diameter circle at ground level. The collimator is constructed to provide an inch of lead shielding for any incident radiation exceeding the entrance angle.

III. Electrical System

Electrical power is supplied by a six kilowatt diesel-powered generator mounted near the rear of the cab. The capacity of the generator allows for operation at altitudes in excess of six thousand feet, which requires that its output be derated by nearly 25%. Besides the electronics, the generator also provides power for a detector heating system. Each detector housing uses high density polyurethane foam for insulation and shock protection, and is internally heated with a variable wattage heat tape which extends the environmental range of the system and lessens temperature dependent effects (detector light transmissivity and gain shift) from winter day/night temperature fluctuations. There is no voltage conditioning system, as all of the AC powered components have broader input power parameters that the regulated output rating of the generator. Regular backup of data to magnetic media restricts the maximum amount of data potentially lost due to power failure.

IV. Electronics System

The electronics system centers around the computer, it either directly controls or provides the data interface with 90% of RTRAK's electronics. Current programming efforts will increase that control to almost 99% of the system. RTRAK's computer is an IBM Model 7532 Industrial PC/AT. It has an 80286 processor, 80287 math co-processor, 640 kilobytes of system memory, two megabytes of RAM disk, a color EGA graphics display, one 5 1/4" high density floppy disk drive, one 3 1/2", 720 kilobyte disk drive, and A Real Time Interface Co-processor (ARTIC, 80126) for RS-232 communications. Data is transferred from the EG&G Model 980 ADC's through a dual port memory interface in the AT. Control of and/or data transfers from six external devices is handled via RS-232 communications through the ARTIC card and seven other devices receive control signals from the EG&G 980's which are among the RS-232 controlled devices (Figure 1).

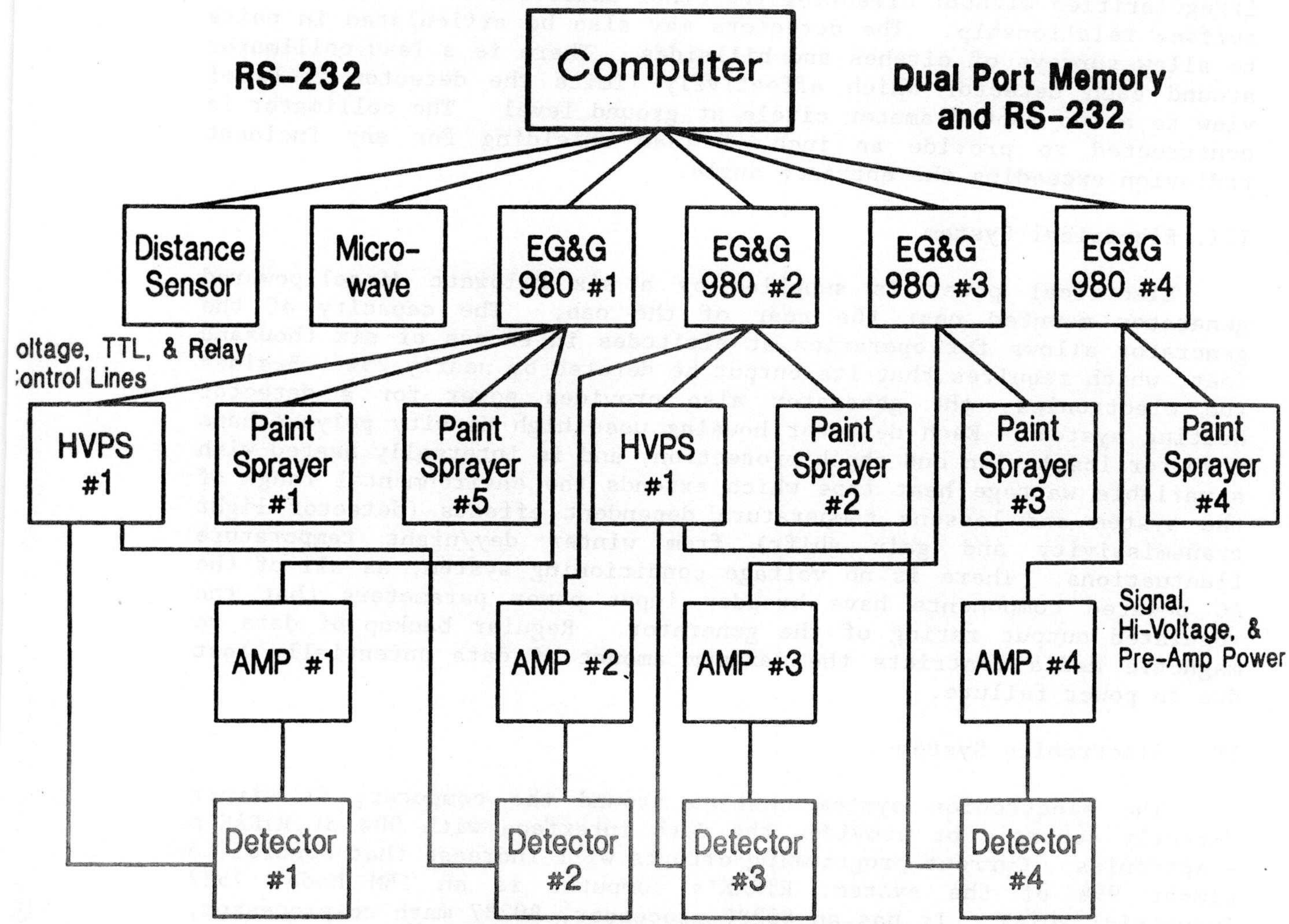

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Figure #1: System Configuration

RTRAK's counting system consists of four 4 x 4 Sodium Iodide [NaI(Tl)] detectors, each with its own amplifier and ADC. Consideration was given to using extruded or polysyn type NaI's, but the additional cost and delay in acquisition did not seem to warrant their use. Additionally, the "natural" NaI crystal, while tending to be more susceptible to mechanical shock, has better thermal shock characteristics. The presumed operating parameters of RTRAK made thermal shock the most likely of the two, since the kinds of acceleration required to generate a mechanical shock hazard did not seem likely at the proposed operating speeds with the foam packing used. In retrospect, the most sensitive component of the detectors has proved to be the photomultiplier tubes, possibly due to vibration. Five inch photomultiplier tubes are used to enhance the detector resolution. All but one has been replaced as of this date, but none of the crystals have been damaged. The original detector assembly has been slightly modified; the original detector had the tube base preamp soldered directly to the photomultiplier leads. We have since modified them all to use a plug in assembly so that repair of a detector can actually be accomplished in the field without much difficulty.

RTRAK has two systems for determining position - a simple distance measurement device and a sophisticated microwave positioning system. Both are linked to the computer by RS-232 data links. The distance measurement device simply counts pulses originating from a magnet mounted on the drive shaft. The pulses are conditioned and then input to a counter. The counter is capable of interrogation via RS-232 and returns the number of events counted since it was last reset. Prior to operation, a simple calibration of pulses per foot is done by driving a known distance at a set gear and engine RPM. This device is used primarily for road surveys where x, y coordinates are not important. Within the same gear, variations in engine RPM have very little effect upon the calibration; most of the device's inaccuracy is due to tire slippage. The microwave positioning system sued is manufactured by Motorola's Government Electronics Group and is typically used for dredging operations and limited navigation of small vessels. Its range varies with the choice of antennas; RTRAK's system has an effective distance measuring capability of from a few hundred feet to 13 nautical miles, with one meter accuracy. The central interrogation unit and processor are mounted in the tractor and two remote transceivers are positioned on the property. The operator inputs the location of the remote units to the system prior to start up, and the processor then calculates the distance between them. It continuously determines the distance to each of the remotes from the central unit during operation and calculates position. Changes are now being considered to RTRAK's software to use the distance measurement system as a back check on the microwave to catch bad measurements caused by signal reflection and cancellation. Corrections could then be made using the distance traveled and the direction of travel from the last set of data. Such a filter is already in use in the report generating software, using a running average of speed and direction.

V. Software

Software development for RTRAK has been a dynamic process for the last year and a half. The addition and deletion of functions with use and improved experience in the field has resulted in an operating system which is responsive to actual field conditions. All of RTRAK's software is written using Microsoft's Quick Basic. Currently, RTRAK's software offers the following functions:

1. System setup - a master menu of operating parameters which are written to a data file for use by other parts of the software.

2. Detector checkout - a spectral data acquisition and display program used to check system gain and check source tests. The spectra may be examined by a moveable cursor and optionally stored on magnetic media for future examination.

3. Survey operation.

4. Manual communications with the EG&G 980's - allows the operator to manually communicate with the 980's for testing, or to utilize some of the 980's other unctions. It also is used for some maintenance functions with the paint sprayers.

5. Display of previously recorded spectral data.

6. Display of previously recorded survey data; can be used to regenerate the display prior to restarting a survey.

All of the above are called from a master menu. On system power up or restart, all of the software required for normal operations are transferred from floppy disk to a two megabyte virtual disk and the system initialization program starts. All software runs from the virtual disk, since magnetic media are subject to possible damage from vibration incident to the vehicle operation. The initialization software primarily sets up the ARTIC to handle communications; it opens the I/O ports as if they were files and gets the DOS identifier for each. The operator is queried for any bad detectors (one is allowed during operations), then the master menu program is called. Upon exiting any of the programs which may be called from the master menu, the software returns to the master menu.

Instructions for the software about the survey parameters are input to the system setup program. It requests that the operators define the type of survey so that the system knows how to use the positioning equipment. Survey area boundaries are input in order to scale the display for mapping. The next input is for the survey activity limits, what is to be displayed as hot, and whether or not hot spot painting is desired. Finally, the operator is requested to input the detector calibration and background factors for each detector. An infrequently used option to the setup program can be used to help the operator set up a predefined track line survey; coordinated starting position, direction of travel from that location, and which side of the initial track line the next survey line will be on. Since the real world seldom allows straight, parallel lines, most surveys are not planned out in that manner. In normal operation, the microwave system allows the mapping functions to track RTRAK wherever it travels with in the survey area.

Prior to actually starting any survey measurements, and periodically during a survey, it is necessary to check the detector energy calibration and perform a count rate test with a known source. Additionally, when surveying for Ra-226 in soil, periodic background checks are required to test for changes in soil gas equilibrium due to soil moisture or changing atmospheric conditions. "Spectrum", the detector checkout routine, allows the operator to collect spectrums for each detector individually, displays count rate totals for the predefined regions of interest, and provides a user operable cursor that reads out in channel number and count rate for that channel. The operator may save any spectrum on disk if desired. The spectral data is saved with user input identification, detector number, date, time of day, and count time. Input to Spectrum consists of detector number and count time.

The operations program, "Survey", can run in three separate modes. One option from the main menu is "Cal-Demo", short for calibration or demonstration. This method of operation does not use the microwave system for positioning information, but requires the track line setup option from "Setup". The purpose of this option is to allow the detection system to operate in its normal survey mode when actual position is irrelevant. If the detector calibration and background factors are set to 1 and 0 respectively, the "Hot" parameter to 5, and the paint option turned on, the system will paint out a pattern on the ground which allows soil samples to be collected which can then be related to a single detector reading. This is the method used to calibrate to a single detector reading. This is the method used to calibrate RTRAK at a site. Typically 20 to 25 samples are collected for each detector in this manner at a site. The next mode of operation uses only the distance measurement device and is called the "Range" mode in the program "Setup". The only use of this mode of operation to date, where the relevant position information is the distance from a known starting point to the reading, has been for road surveys. The third, and most common, method of survey operation utilizes the microwave positioning system. Other than the method utilized in determining position, the survey program functions the same for all modes of operation. A display map is outlined on the screen and corner coordinates displayed. An information display across the top of the screen identifies the survey, site, and some of the hot key functions. The system waits for the operator to press any key to begin the survey. When the survey begins, an initial determination of location is made, the counters cleared, and data acquisition started. Once data acquisition begins, a timing delay starts to time the acquisition period.

In February of 1987, the D.O.E. project manager for UMTRA requested that MK-Ferguson and Chem-Nuclear Systems make the development of an automated, radiation survey vehicle a top priority. The rationale behind RTRAK's urgency was the potential cost savings to the UMTRA project which could be realized with such a tool. As compared to the soil sample verification procedures then in place for demonstrating compliance with Ra-226 cleanup criteria, RTRAK was estimated to be capable of saving the project over two million dollars in direct manpower costs. The potential savings in construction costs arising from expeditious cleanup evaluation, rather than waiting for soil sample analysis results, were not estimated, but, depending upon the scale of the contractor's operation, could be worth tens of thousands of dollars per day.

In July of 1987, the constructed vehicle was delivered to the project office from the fabrication facility ready for testing and software development. The first field trails were conducted in September of 1987 and by November of 1987, many of the current survey procedures were well developed. During the winter of 1987-88, RTRAK was mostly idle waiting for site work to restart in the spring. In February of 1988, RTRAK conducted a perimeter survey at one UMTRA site which covered a five mile long boundary fence. A serpentine pattern was employed which covered a swath 400 foot wide, for a total area of over 200 acres. The survey required only three weeks to complete.

Following that survey, RTRAK's hardware was upgraded to include the ARTIC communications. This replaced an intelligent RS-232 switch which caused an error with the previous device every time it switched to a new device. The new communications were tested during a site survey conducted in April which covered over 300 acres. In May of 1988, RTRAK surveyed a 55 mile long haul road in one week (four passes at 5 miles per hour).

In August of 1988, RTRAK returned to the location that it surveyed in May and began the verification survey there. The beginning of that survey, 13 months after RTRAK was completed, marked the culmination of RTRAK's first year of development and use.

The use of RTRAK as a verification tool, approved by the Albuquerque Operations Office of the Department of Energy and the United States Nuclear Regulatory Commission's Denver Office, is an important milestone in the development of computer based data acquisition systems. The key to effective, efficient environmental monitoring and remediation of large land areas in the future will be RTRAK and systems like it.