RAD RELAY RADIOLOGICAL DATA LINK DEVICE

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The RadRelay effort developed small, field appropriate, portable prototype devices that allow radiological spectra to be downloaded from field radiological detectors, like the identiFINDER-U, and transmitted to land based experts. This communications capability was designed for the U. S. Coast Guard (USCG) but is also applicable to the Customs and Border Protection (CBP) personnel working in remote locations.

USCG Level II personnel currently use the identiFINDER-U Hand-Held Radioisotope ID Devices (HHRIID) to detect radiological materials during specific boarding operations. These devices will detect not only radiological emissions but will also evaluate those emissions against a table of known radiological spectra.

The RadRelay has been developed to significantly improve the functionality of HHRIID, by providing the capability to download radiological spectra and then transmit them using satellite or cell phone technology. This remote wireless data transfer reduces the current lengthy delay often encountered between the shipboard detection of unknown radiological material and the evaluation of that data by technical and command personnel. That delay is reduced from hours to minutes and allows the field located personnel to remain on station during the inspection and evaluation process.

I. INTRODUCTION

Before this program, there was no capability to transmit HHRIID radionuclide spectral data from ships being surveyed by USCG Level II personnel back to the reachback/triage technical support personnel for help in resolving material identification questions. Data from the USCG identiFINDER-U's had to be downloaded to a computer and e-mailed to Laboratories and Scientific Services (LSS), which in some cases would require physically transporting the identiFINDER-U back to shore, or to a cutter with on board internet connections. Having a device that will allow communications of spectral data via satellite communications is essential to support active boarding parties in the open water patrolled by the USCG.

The goal was to develop transmission units that would link the existing identiFINDER-U radionuclide spectrum analysis devices, which are deployed at sea or other remote locations, to technical and supervisory personnel in mainland locations. The system could be applied to any similar device. The data gathered from one or more handheld units would be loaded into a field archiving and transmission unit that would relay this information to a sister unit on the mainland by the usage of IRIDIUM satellite phones. A similar unit at the mainland location would provide the data to the appropriate technical or supervisory personnel for action.

The RadRelay interface device would be a battery powered, waterproof, impact resistant, field appropriate device that could be carried on the boarding vessels or directly to the location where the HHRIID's are used. The identiFINDER-U device(s) would then be plugged into the interface for immediate download and transmission of radiological data to a land based unit.

II. DEVELOPMENT DETAILS

RadRelay has been developed under Department of Homeland Security for the USCG in support of their radiological inspection and evaluation efforts. Phase 1 provided a fully functional demonstration of the technology needed to link the currently deployed identiFINDER-U devices. Phase 2 provided two field units for deployment, testing, and evaluation. The originally defined Phases are now complete and included the following:

Phase 1 Program:
The field radiological spectrum analysis identiFINDER-U units were coupled to data handling computer facilities to evaluate their characteristics. The characteristics of the IRIDIUM satellite phone, the USCG standard satellite phone, would be coupled to the

identiFINDER-U requirements, and a user friendly interface would be defined that would be suitable for use on board ship with minimal training.

The goal was a very simple plug-in device that would not require any computer skills to achieve the capture and transmission of spectral data to a mainland location. The small battery powered, waterproof unit would resemble a "PDA", although it would differ significantly internally from a public sector PDA, and have a screen and a minimum of operator command buttons. The latter was implemented as a button to download the data from the identiFINDER-U and another button to transmit the data. The system would interface to an existing, unmodified, USCG IRIDIUM satellite phone for transmission of the data to a mainland location.

The hardware at the mainland location was originally designed to be a similar satellite phone link and local computer (e.g. laptop or desktop). The data presented at the mainland location to the technical expert would be identical to that seen by the field inspector, to allow for evaluation of any questionable readings or results. Since IRIDIUM linkage is to be used, the technical expert location(s) can be located anywhere desired. The final implementation also provided for a land line to computer connection that was deemed more convenient in many cases.

Phase 2 Program:
Based on the successful completion of Phase 1 issues related above, two sea deployment ready prototype systems were built and provided for field testing and evaluation.

As this work progressed it became apparent that Phase 2 would need to be expanded to include the evaluation of using cell phones rather than just satellite phone as data links. Satellite phones are the method of choice for far off shore applications, but cell phones have many advantages when used on or near shore. Since the cell phone option is beyond the original scope and would have delayed the completion of the satellite phone version, the cell phone version will be discussed as a future option below.

II. COMPONENTS

II.A. System Overview

The RadRelay development uses the existing USCG deployed identiFINDER-U devices and provides all hardware and software needed to communicate from virtually any location on the planet to shore based technical experts. Figures 1, 2, and 3 show the general system layout and schematic of RadRelay.
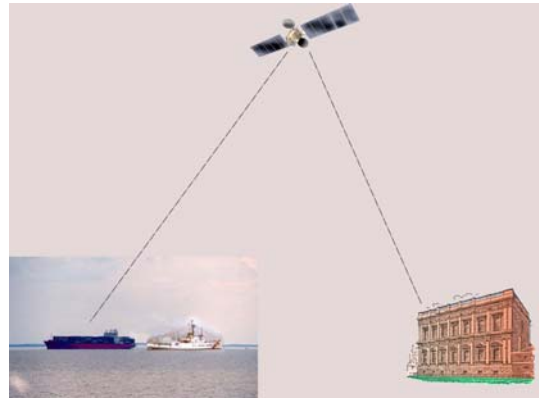

Figure 1 - Ship to Shore Linkage

Figure 2 - Schematic of Shipboard Portion (Phase 1)

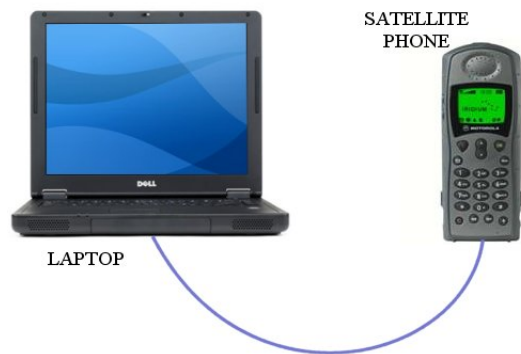**Figure 3 - Schematic of Shore Portion (Phase 1)**

The currently deployed identiFINDER-U device(s) would be used, by the USCG personnel, exactly as they are now operated, to detect and analyze the presence of radiological materials. The currently used identiFINDER-U will output the raw data of a detected spectrum to another device, through a serial port. The identiFINDER-U's can accumulate up to 50 spectra and

will attempt to match any detected spectrum to an internal library.

If an unknown spectrum, a mixed spectrum, or a significant spectrum is detected, there is a need to relay the details of the detected spectrum to shore based experts or response control personnel. Prior to this work, the only means to accomplish the data relay was by returning the identiFINDER-U to shore or to a larger support vessel and utilize email with a prolonged response delay.

The RadRelay program is aimed at providing the technology to directly couple the identiFINDER-U output to a suitably portable device that would capture the data, reformat it appropriately, and transmit it using a USCG satellite phone to shore based facilities. The satellite phone methodology was chosen since it would meet all off shore data transmission needs regardless of location. Subsequent work, noted below, uncovered the need to also evaluate the use of cell phones for near shore or on shore applications, where the cell phone could be a better choice, and this option will be addressed in later sections.

II.B. Radiological Detection

The identiFINDER-U devices are now in wide usage in the USCG and other services for rapid detection and analysis of radiological spectra. For the purpose of this program, the adequacy of that detection and initial analysis was deemed to be adequate. The RadRelay program was aimed specifically at getting the spectrum data to the on shore radiological technical experts for subsequent analysis.

The identiFINDER-U devices, which are now in common use in two configurations, have a data access port that can provide a raw output of the analysis data in their memory. The data output requires reformatting to make it compatible with the receiving computer's spectrum analysis software.

II.C. Data Processing and Communications Interface

The data output capabilities of the identiFINDER-U devices were determined to be adequate but inflexible. A combination of requests from an external device (computer, PDA, etc.) would result in all the internal stored spectra being output sequentially. However, the ability to control or modify this output beyond its predetermined form was not deemed to be a good way to proceed.

It was also determined that the satellite phones were equally inflexible in what they were designed to accommodate, relative to inputs and expected outputs. For the current work we were using the USCG Motorola

IRIDIUM devices but it is believed that this would apply equally to most similar devices. Satellite phones were also determined to have a significant overhead of instructions (i.e., numbers of buttons that had to be pushed to make and receive data transmissions), that it would be preferable for field personnel to not have to endure.

It was determined that the most effective method of interfacing the identiFINDER-U device to a satellite phone and dealing with all of the transmission overhead, was to provide a flexible external device that would combine all of the following functions:
- Capture the entire data package from the identiFINDER-U as it was downloaded.
- Extract from the data package the information that was required for transmission.
- Add data to the identiFINDER-U data that was needed at the shore based end that was not in the download package, including identification of which IdentiFINDER-U was connected, time, date, etc.
- Handle all of the transmission overhead of the satellite phones, include connect sequence, phone number, and answering.
- Reduce the operator burden to pushing a couple of buttons.

A small subset of available rugged PDAs was found that had all of the attributes that would allow them to perform the above functions. Most general purpose PDA's were not acceptable choices. The communication device had to support a series of software requirements, including both availability of COTS software packages and the ability to add functions to complete the system. Details of the software are given in following sections.

II.D. Hardware and Packaging

The expected environment in which the RadRelay would be deployed defines a number of hardware and packaging parameters that must be addressed for a successful deployment. Phase 1 was limited to a technology demonstration with Phase 2 addressing all of the deployment specific issues. However, a number of design and operational issues were uncovered during Phase 1 and those that did not affect cost or schedule issues were included in the Phase 1 demonstration.

Previous field experience at the Savannah River National Laboratory (SRNL) involving both terrestrial and maritime operations, and more specifically the deployment of SRNL personnel to the World Trade Center recovery efforts assisted in defining certain attributes of a successful field system. These would include being rugged, small, waterproof, and simple to

operate. It would also require minimal training, and tolerance to a wide range of voltages, for both charging and operation. All of these items were addressed fully in Phase 2.

III. SOFTWARE DEVELOPMENT

III.A. Current Capabilities & Limitations of the RadRelay Software

The RadRelay software was intentionally divided into three independent pieces of software: RadRelay, Spectrum Download Program (SDP), and Transfer Files. The reason for this is so that the capabilities of the system could be expanded in the future by adding download programs for other instruments. Also, the file transfer portion is very generic and will transfer any file type (radiation data, sound file, video file, image file, etc.).

III.B. RadRelay V1.0.0

CAPABILITIES AS DESIGNED (Figure 4):
1. This software automatically runs when the RadRelay PDA is turned on.
2. The Download button runs the Spectrum Download Program.
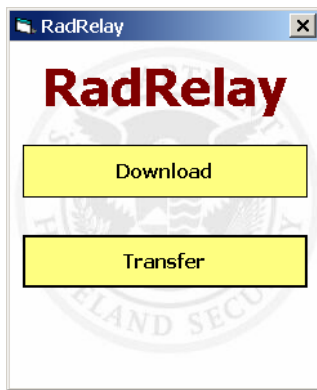3. The Transfer button runs the Transfer Files software.

Figure 4. - RadRelay

LIMITATIONS OF THE CURRENT DESIGN:
1. The spectrum "data" directory is located in a very obscure subdirectory which makes it hard to find when adding or deleting files.
2. There is no Administrative Area: that allows the spectrum files to be deleted or viewed or allows other files to be added. Also, there is no place to create and maintain a phone number directory.

III.C. Spectrum Download Program (SDP) V1.0.2

CAPABILITIES AS DESIGNED (Figure 5):
1. This software only works with Target Instruments or Thermo brands of "identiFINDER." When the software is run, the operator is presented with a choice of two things: "Download Actual Spectrum" and "Download All Stored Spectra."

2. "Download Actual Spectrum" will retrieve the spectrum that is currently in the identiFINDER's memory (i.e., the spectrum that was just acquired) and save the spectrum to a disk file on the PDA.

3. "Download All Stored Spectra" will retrieve all spectra that have

Figure 5. – Spectrum Download Program

been saved in the identiFINDER's flash ram. This can be as many as fifty spectra. Each spectrum will receive a unique name based on the serial number of the identiFINDER, and the date and time the spectrum was taken. Each file is then saved in the "data" directory. As of now, the "data" directory is a fixed location on the PDA.
4. Multiple identiFINDERs may be consecutively connected to the PDA to have their spectra downloaded and saved to the "data" directory.
5. When either of the download buttons is clicked, the serial number of the identiFINDER is read and displayed at the bottom of the screen. This confirms that the PDA and the identiFINDER are communicating.
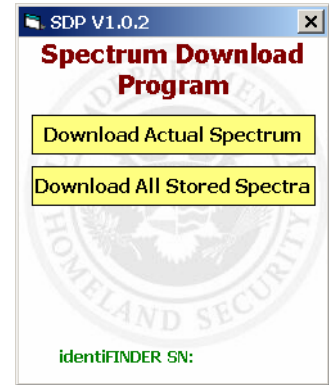
LIMITATIONS OF CURRENT DESIGN:
1. Cannot download just one stored spectrum. The identiFINDER interface was written to make this impossible.

III.D. Transfer Files V2.0.0

When the software is run, the operator is presented with a choice of two ways to transfer files: "Satellite Phone" and "Cellular Phone." At this time, both buttons will dial a predefined phone number using the Satellite Phone. The Cellular Phone portion is not yet complete because of delays by the vendor.

Once a button is selected, this software automates the execution of a commercial communications and file transfer package (called vxHpc) via a script. A script is a high level set of instructions that commands the commercial software to perform specific tasks. It is very similar to a macro in Excel.

Before this program is run, a standard Windows program called HyperTerminal must be run (on the remote computer) and setup appropriately so that it is waiting for a data phone call and handle Zmodem protocol file transfers.

CAPABILITIES AS DESIGNED (Figure 6):

The script performs the following functions:

1. Dials the phone number of the remote phone.
2. Waits for the phone on the other end to pick up and create a connection
3. Once the connection is established, the script transfers all the files in the "data" directory using the Zmodem protocol and provides a very clear feed back window with the following information:
   a. The name of the file currently being transferred
   b. The total number of files to be transferred
   c. The number of files already transferred
4. Once all the files are transferred, the script automatically exits the vxHpc program and exits the Transfer Files program.

Figure 6. – Transfer Files

LIMITATIONS OF CURRENT DESIGN:

1. The IRIDIUM Satellite Phone Data Connect only has a 2400 baud throughput
2. It is difficult to change the phone number that is dialed.
3. The dialing user interface is not very informative.
4. The user cannot select individual file to be transferred. By default, all files in the "data" directory are transferred.
5. Files are not encrypted.

IV. TECHNOLOGY DEMONSTRATION DETAILS (PHASE 1)

The RadRelay was tested and demonstrated at SRNL in a fully prototypic configuration. The use of satellite phones on a government facility comes under a variety of restrictions, so the work was conducted at an area where unrestricted usage was allowed. A DVD was created of the test work prepared, so that the results could be discussed in any location. The demonstrated equipment was carried to a meeting in Washington DC and presented to Department of Homeland Security personnel.

The demonstration layout is shown in Figure 7 and the external antennas are shown in Figure 8. Normal usage in an open environment, such as at sea, would not require the external antennas but this test work was conducted in a metal building, which limits satellite phone effectiveness.
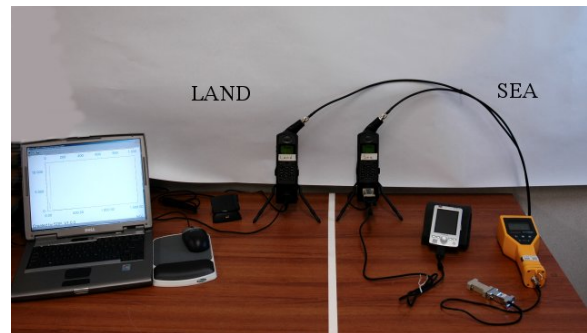
Figure 7 - RadRelay Technology Demonstration Setup

Figure 8 - External Antenna Setup

The arrangement shown in Figure 7 is divided into the "sea" and "land" sections with the only linkage between these being by the two satellite phones. Even though they are side by side a round trip to a low earth orbiting satellite is between the two portions. All portions of a fully functional system are shown in this figure. The components as shown in Figure 7, moving from right to left are as follows:

1. IdentiFINDER-U device (standard device borrowed from the USCG for this demo)
2. Interface cable attached to identiFINDER-U to allow interconnection to PDA

3. PDA shown with a second interface cable that adapts it to a Motorola IRIDIUM satellite phone (borrowed from the USCG for this demo)
4. A modem interface and stand added to Motorola phone to link to PDA (black section directly below phone).
5. Another Motorola satellite phone identical to the one described above.
6. Interface cable to a generic laptop computer that serves as the land based portion of the system (almost any Windows based machine could be here).

Not shown in the figure, but necessary, is the following:

1. Software package in PDA that combines COTS software with SRNL provided software to do all the interfacing.
2. Software in the laptop that consist of COTS software for modem operation and identiFINDER-U vendor supplier software.

The sequence of operation is as follows, with the RadRelay PDA operation steps given in a following section:

1. IdentiFINDER-U is used in the standard USCG manner to inspect and capture radiological spectrum as needed, with a maximum of 50 spectra being captured by each identiFINDER-U (maximum is a identiFINDER-U limitation).
2. One or more identiFINDER-U device(s) are connected to the RadRelay interface PDA, consecutively, and all of their captured spectra are downloaded into the RadRelay, utilizing a few on screen buttons. Additional data is automatically added to the downloaded information, as desired, including serial number of the particular identiFINDER-U from which the data came, etc.
3. RadRelay PDA is plugged into the "sea" based satellite phone and "sea" to "land" transmission is instigated and controlled by the RadRelay PDA by utilizing a few on screen buttons, internally stored phone numbers and satellite dialing sequences.
4. The "land" based satellite phone answers automatically and transmits incoming data to the generic laptop computer.
5. Laptop software, when triggered by the operator, displays the spectrum data of any of the download spectrum for appropriate USCG response.
6. Termination of the call at both phones is also under automated control.

The time required for the entire process is dependent on a number of satellite phone factors. The various components take differing amounts of time to accomplish their tasks, specifically, it takes approximately 1 second per spectrum for the identiFINDER to PDA transfer, but it takes 20 seconds per spectrum for the PDA through satellite phone linkage.

The relevant hardware issues noted above were addressed on this "first cut" by the selection of demonstration equipment of appropriate size and complexity. Figure 9 shows the hardware as packaged for the technology demo and field tests.

Figure 9 - RadRelay Packaged for Demo & Field Tests

V. SHIPBOARD FIELD TESTS (PHASE 2)

The on-the-water field test of the RadRelay system was successfully completed at a USCG facility in Yorktown, Virginia during August 2006. The test successfully demonstrated the remote transmission of radiation spectral data collected during the field exercise to technical experts located at the CBP-LSS facility. Both of the prototype RadRelay units produced by SRNL were utilized during the testing sequence. The USCG personnel involved in the testing were extremely pleased with the results and retained one of the prototype units for their continuing use during ongoing operations at Yorktown. Figure 9 shows the tested components.

Three separate sets of radiological spectra collected on USCG identiFINDER-U units were individually transmitted by satellite phone and the transmitted data was evaluated by LSS personnel. Each separate transmit/evaluate cycle (which included three spectra files each) took only five minutes.

The current funding was for a satellite phone system that could capture identiFINDER-U radiological spectra

and transmit them to a remote location, where experts could evaluate important or questionable captured spectra. All portions of that task were accomplished with the field demo.

An additional terrestrial field test, which was entirely successful, was conducted during October 2006 at a remote, offsite, facility. A revised computer facility had been placed in service at LSS and SRNL tested it for data transmission adequacy, in conjunction with a spectra delivery rate test. Twelve spectra files of interest collected at SRNL were successfully transmitted to LSS, by RadRelay using a satellite phone, in approximately four minutes, including connection establishment time. Since the current USCG satellite phones are by far the slowest method of communication (as compared to cell phones or newer satellite phones), these results are the "worst case" and still very adequate.

During and after the Yorktown field trial, a number of items were identified by the SRNL and USCG personnel that could be categorized as Assistance to LSS and Field Fix Items. They are covered below.

V.A. Assistance to LSS (The shore based facility responsible for analysis of radiological spectra of interest encountered by field teams)

    (1) The temporary setup of data facilities for receipt of satellite or cell phone transmitted data was established through consultation with LSS computer technologies. – **Status Complete**

    (2) Provide recommendations to LSS concerning a permanent computer data receipt station, including recommendations for computer modems compatible with current digital phone system. Note: Traditional phone modems can not function on digital phone systems as is used at LSS.

    (3) Assist LSS in defining the protocol(s) for data receipt and analysis, such as tracking numbers of files sent versus received, file verification, and response back to field.

    (4) Provide LSS with software and/or recommendations for keeping data organized and identified when potentially receiving multiple data transmissions from multiple field locations.

V.B. Field Fix Items

    (1) A timing issue between the PDA used to collect the IdentiFINDER-U data and transmit it by way of satellite phone was noted and fixed during the demo. – **Status Complete**

(2) SRNL personnel noted the desirability for real time feedback to the operating USCG personnel of the transmission actually taking place and progress in the transmission. A field transmission can involve a large number of spectra items and/or data files and satellite phone transmission is slow. SRNL added to one of the units a real time display that showed what was currently being transmitted – **Status Complete**

VI. FINAL DEVELOPMENTS

Several items that are beyond the original scope of the RadRelay program are noted below as considerations towards future systems and programmatic clarifications.

VI.A. RadRelay Cell Phone Option

Both prototype RadRelay units have been equipped for inclusion of cell phone modules within the PDA, to support future cell phone or satellite phone usage. As noted previously, the cell phone option was not in the original scope of this work but it was believed to be a very desirable long range need.

VI.B. LSS RadRelay Receiving Station

LSS is the designated facility to evaluate and resolve radiological spectra of interest. In this capacity, they would be the primary point where radiological spectra are sent from the field. They have not previously had a receipt facility tailored to their portion of the overall RadRelay task.

A dedicated LSS RadRelay receiving capability must be in place before a large number of RadRelay units are placed in the field. This dedicated capability would consist of a computer with modem connected to the phone system. It would not require a satellite phone. Also, SRNL highly recommends automating the LSS receiving capability.

SRNL's vision is a computer system that will:
- Automatically answer a phone call.
- When a connection is made and a file transfer is started, create a new folder name with the current date and time put all received files in this new folder.
- Allow old folder/files to be deleted.
- Allow folders/files to be copied to a removable device or disk

As part of the system setup, an LSS Conduct of Operations needs to be defined that will clarify the following:

1. How will LSS be notified that data files are being transferred?
    a. Voice phone call?
    b. Email?
    c. Pager?
2. Will the Receiving Station be manned?
3. How will the number of files received be verified?
4. How will the results of spectrum analysis be communicated back to the sending party?

VI.C. Assistance to LSS

All work to date has been with the Motorola IRIDIUM satellite phone which is the standard satellite phone of the USCG. It is realized that this could change in the future and the RadRelay system would be required to adapt accordingly. Most any satellite phone will work with RadRelay as long as the following conditions are met:

1. The satellite phone has an RS-232 port
2. An RS-232 cable exists or can be built to connect the satellite phone to the PDA
3. The satellite phone is capable of making a data call
4. The proper data call dialing codes are known for the satellite phone

For any given satellite phone (besides the IRIDIUM), some engineering may be required.

Caution Concerning identiFINDER Firmware Versions:

The identiFINDER vendor (Target Electronics) has produced several versions of the firmware within the identiFINDER and several versions are currently in use within the USCG. SRNL has had experience using identiFINDERs with different firmware versions, and has identified several differences in the various versions.

SRNL can verify that version 3:862E works fine with the RadRelay Spectrum Download Software. However, version 3:876E reports the wrong filename, start time, and stop time with RadRelay and Target's software. According to Target (the manufacturer of the identiFINDER), firmware version 3:879E corrects the problems with version 3:876E, but SRNL has not confirmed this due to not having an identiFINDER with this firmware version.