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Aerial Measuring System Technical Integration

Annual Report 2002

June 2003

Remote Sensing Laboratory

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Contents

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Acronyms

ADC	analog-to-digital converter
AFE	analog front end
AFRL	Air Force Research Laboratory
AGL	above ground level
AMS	Aerial Measuring System
ANSI	American National Standards Institute
ARAC	Atmospheric Release Advisory Capability
ARCS	airborne radiation computer system
ASPRS	American Society for Photogrammetry and Remote Sensing
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
ATCOR	[software]
BN	Bechtel Nevada
CD	compact disk
CM	consequence management
COIS	Coastal Ocean Imaging Spectrometer
COTS	commercial-off-the-shelf
CPU	central processing unit
CZT	cadmium-zinc-telluride
DARS	Data Archival and Retrieval System
DEM	digital elevation model
DGPS	differential global positioning system
DOE	U.S. Department of Energy
DREAMS	[gamma detection pod]
ENVI	[software]
FARMS	field airborne radiological measurement simulator
FIDLER	field instrument for detection of low energy radiation
FWHM	full width at half maximum
FY	fiscal year
GCP	ground control point
GCS	geometric correction system
GENIE	GENetic Imagery Exploitation [software]
GIS	geographic information system
GPS	global positioning system
GSD	ground sampling distance
GUI	graphical user interface
HPGe	high-purity germanium
HSI	hyperspectral imagers

IAEA	International Atomic Energy Agency
IDL	[software]
IFSAR	interferometer synthetic aperture radar [mapping system]
IR	Incident Response
ISO	International Organization for Standardization
JT	Joule-Thompson
LIDAR	light detection and ranging [mapping system]
LUT	lookup table
LWIR	long wavelength infrared
MCA	multichannel analyzer
MCNP	Monte Carlo N-Particle
MDA	minimum detectable activity
MPS	multiple platform system
MWIR	mid-wavelength infrared
NASA	National Aeronautical and Space Administration
Na(Tl)	thallium-activated sodium iodide
NBL	New Brunswick Laboratory
NIMA	National Imagery and Mapping Agency
NIR	near infrared
NNSA	U.S. DOE, National Nuclear Security Administration
NTS	Nevada Test Site
PC	personal computer
PEC	Paulus Engineering Company
R&D	research and development
REDAC	Radiation and Environmental Data Analyzer and Computer
REDAR	Radiological Environmental Data Acquisition Recorder
RSL	Remote Sensing Laboratory
SNM	special nuclear material
STL	Special Technologies Laboratory
SWIR	short wavelength infrared
TI	technical integration
TIR	thermal infrared
UAV	unmanned aerial vehicle
USGS	U.S. Geological Survey
UTM	[software]
VIS	visible
WF	Warfighter

Introduction

Fiscal Year 2002

Fiscal Year 2002 is the second year of a five-year commitment by the U.S. Department of Energy, National Nuclear Security Administration (NNSA) to invest in development of new and state-of-the-art technologies for the Aerial Measuring Systems (AMS) project. In 2000, NNSA committed to two million dollars for AMS Technical Integration (TI) for each of five years.

The tragedy of September 11, 2001, profoundly influenced the program. NNSA redirected people and funding resources at the Remote Sensing Laboratory (RSL) to more immediate needs. Funds intended for AMS TI were redirected to NNSA's new posture of leaning further forward throughout. AMS TI was brought to a complete halt on December 10, 2001. Then on April 30, 2002, NNSA Headquarters allowed the restart of AMS TI at the reduced level of $840,000. The year's events resulted in a slow beginning of several projects, some of which were resumed only a few weeks before the AMS TI Symposium held at RSL on July 30.

AMS TI Five-Year Plan

NNSA formed an aggressive five-year plan for AMS in December 2000. The plan provides a roadmap for a smarter, lighter, faster system that requires the integration of state-of-the-art technologies with the current program. The objective is to reduce the footprint of personnel and assets at the incident site. The co-objectives are to maintain a rapid response capability, to quickly ship the data acquired in real time via telemetry or other conduits to home teams of analyzers and to quickly provide the information from these analyses to decision makers at NNSA.

We have constructed from the *AMS Five-Year Plan* a technology development program with six major emphasis areas:

- Radiation Exposure Rate Mapping
- Radiation Spectral Mapping
- Photo and Spectral Imaging
- Modeling and Simulation
- Data Telemetry and Networking
- Unmanned Aerial Vehicles

Within each of these areas, one or more significant activities are proposed for fiscal year FY 2003. The program takes a phased and measured approach. In the first phase we carefully prepare researched studies on feasibility and available technologies, followed by design and configuration management decisions. The intermediate phase finds development of new devices, equipment, software and hardware support and processes at the prototype stages. Once satisfied with the prototypes, we proceed to the fabrication stages. Based on our priorities, some of the six major emphasis areas will have made substantial progress, others less.

Not all the tasks will proceed to the next evolutionary step. Data supporting our conclusions establishes a basis for making iterative corrections to the *AMS Five-Year Plan* and process, better enabling us to reach NNSA goals efficiently and quickly. For instance, we learned that a "black box" that enables any of our detector packages to interface with any type of aircraft platform, power or global positioning system is not practical. Military telemetry systems have the capability AMS needs to transmit data real-time to RSL as the *AMS Five-Year Plan* mandates. However, we do not have the required access to these military channels, and it is not practical to try to replicate the military infrastructure. On the other hand, we have made a great deal of progress in telemetry of small radiation datasets in real-time, a valuable new asset for NNSA for radiological incident response.

Work Scope Acceptance Process

An intense process of peer and scientific review established a set of work scopes that, if funded at the full two-million-dollar commitment made by NNSA, would make significant advances toward the objectives laid out in the *AMS Five-Year Plan*. A broad request for proposals throughout Bechtel Nevada announced the standardized format, guidelines and schedules for a fair and user-friendly proposal submission process. A Review Committee of senior and experienced technical and scientific professionals analyzed 34 proposed work scopes, including those interrupted and stopped in. On July 30 and 31, 2002, the AMS TI Symposium 2002 was held at RSL and included the Special Technologies Laboratory (STL) and RSL – Andrews via video teleconference. On July 30, all TI work for was briefed, reviewed and results provided. On July 31, the Radiation Group; Imagery Sciences Group; and Networking, Databases, Telemetry and Unmanned Aerial Vehicle (UAV) Group reviewed and ranked proposals.

The Review Committee reconciled the Groups' three lists into one single set using input from the Symposium participants; values, goals, and objectives of the *AMS Five-Year Plan*; scientific merit and likelihood of success. Discrimination between TI, Operations and Capital Equipment categories was also determined before providing the FY 2003 final product. Finally, the recommended AMS TI work scope was forwarded to NNSA Headquarters for assessment and action.

AMS TI Results

The results of the AMS TI projects for are reported in the pages that follow. The history in conceiving, proposing, approving, implementing and executing these projects is nearly identical to the process employed at this year's AMS TI Symposium. Preliminary results for each of these projects were reported at the Symposium; the final report for the 2002 work is presented in this booklet. The successes of the AMS Simulator, Multi-Platform System and Telemetry show substantial progress toward accomplishing the goals of the *AMS Five-Year Plan*. The true credit for these achievements goes to the dedicated and talented professionals of Bechtel Nevada.

Paul Guss, AMS TI Project Engineer

AMS Technical Integration Team

The AMS Technical Integration Project has put together a team of experts from many disciplines. Team Leaders are employed by Bechtel Nevada at the Remote Sensing Laboratory in Las Vegas, Nevada; the Remote Sensing Laboratory at Andrews Air Force Air Base, Maryland; and the Special Technologies Laboratory in Santa Barbara, California. Where noted, private contractors and private companies are also consulted. Please take a moment to peruse the extensive capabilities of our team.

Ainsworth, Paul J.
Expertise: Programmer in C++, C, Basic
Education: B.S. in Computer Science, University of Nevada Las Vegas, Las Vegas, NV
Professional Experience: 1 year

Becker, Amy M.
Expertise: Remote-sensing analysis, image processing, Geographic Information Systems, photogrammetry; environmental, commercial and government applications
Education: B.S. in Anthropology, M.S. in Forest Engineering/Mapping Sciences, SUNY College of Environmental Science and Forestry, Syracuse, NY
Professional Experience: 4 years

Bluitt, Clifton M.
Expertise: Management; programming, configuration and data analysis
Education: B.S. in Mathematics and Physics
Professional Experience: 9 years in management, 23 years with computer systems

Braithwaite, Kendall G.
Expertise: Software engineering, real-time embedded systems; data acquisition and control.
Education: B.S. in Chemistry, Northern Arizona University, Flagstaff, AZ
Professional Experience: 20+ years

Christel, Lynne M.
Expertise: Image processing and analysis, spatial analysis, surface water modeling
Education: Ph.D. in Watershed Management, University of Arizona, Tucson, AZ; M.S. in Environmental Monitoring, University of Wisconsin, Madison, WI
Professional Experience: 11 years

Chu, Adam C.
Expertise: Hardware/Software specialist, Computer sciences including Cisco Certified Network Associate/Cisco Certified Network Professional
Education: B.A. in Computer Science minor in Psychology, University of Nevada Las Vegas, Las Vegas, NV
Professional Experience: 5 years

Clark Jr., Harvey W.
Expertise: Remote sensing, gamma-ray spectroscopy, health physics, instrument design
Education: Ph.D. in Nuclear Physics, Ohio State University, Columbus, OH
Professional Experience: 22 years

Colton, David P.
Expertise: Remote sensing, radiological and neutron detection systems and analysis, gamma-ray spectroscopy, health physics
Education: M.S. in Atomic and Molecular Physics, University of Texas at Dallas, Dallas, TX
Professional Experience: 27 years

Detwiler, Rebecca S.
Expertise: Nuclear physics, Monte Carlo N-Particle
Education: Ph.D. in Nuclear Astrophysics, University of Notre Dame, South Bend, IN
Professional Experience: 8 years

Doak, Edwin L.
Expertise: Remote sensing, image analysis, instrument characterization
Education: M.S. in Physical Chemistry, University of Chicago, Chicago, IL; M.S. in Electrical Science, University of Michigan, Ann Arbor, MI
Professional Experience: 25 years

Golanics, Charles J.
Expertise: Optical remote sensing hardware calibration, spectroscopy, data acquisition and computer systems
Education: B.S. in Physics, Rensselaer Polytechnic Institute, Troy, NY
Professional Experience: 17 years

Guber, Albert L.
Expertise: Geographic Information Systems, emergency response, emergency management, image processing
Education: B.S. in Earth Science, Pennsylvania State University, University State College, PA; M.S. in Geography, University of Arizona, Tucson, AZ
Professional Experience: 13 years

Guise, Ronald E.
Expertise: Design of analog and digital circuitry for data acquisition instrumentation; primarily focused on gamma and neutron spectroscopy.
Education: B.S. in Electrical Engineering, University of Nevada Las Vegas, Las Vegas, NV
Professional Experience: 12 years

Heimberg, Peter C.
Expertise: Nuclear reactions, particle detectors
Education: Ph.D. in Nuclear Physics, Northwestern University, Evanston, IL
Professional Experience: 14 years

Hendricks, Thane J.
Expertise: Analog electrical engineering, commercial television engineering, nuclear weapon and radiological data systems and analysis
Education: B.S. in Physics and Jr. Certificate in Electrical Engineering, Idaho State College (now Idaho State University), Pocatello, ID
Professional Experience: 45 years

Hyman, Carol A.
Expertise: Certified System Administration, Certified Instructional Designer, experience in training, course development, management and Systems Administration
Education: M.S. in Education
Professional Experience: 40 years

Joines, Christopher J.
Expertise: Embedded systems development, global positioning system and detector integration
Education: B.S. in Electrical Engineering, University of Nevada Las Vegas, Las Vegas, NV
Professional Experience: 10 years

Magner, Marnita A.
Expertise: Programmer in C, C++, Basic, FORTRAN, COBOL, Assembly Language; System Administrator
Education: M.S. in Computer Science, University of Nevada at Las Vegas, Las Vegas, NV; B.S. in Mathematics, Numerical Analysis, University of Washington, Seattle, WA
Professional Experience: 28 years

Marianno, Craig M.
Expertise: Radiation health physics, detector system integration
Education: Ph.D. in Radiation Health Physics, Oregon State University, Corvallis, OR; M.S. in Radiological Health Physics, Colorado State University, Ft. Collins, CO
Professional Experience: 3 years

Mattson, John E.
Expertise: Sensors, sensor technologies, sensor instrumentation, materials characterization, thin film processing, magnetic films, superconducting films, piezoelectric materials and magnetic random access memory
Education: Ph.D. in Condensed Matter Physics, Northwestern University, Evanston, IL
Professional Experience: 12 years

Maurer, Richard J.
Expertise: Gamma-ray spectroscopy, aerial radiological detection, nuclear radiation detectors
Education: Ph.D. in Nuclear Chemistry, Texas A&M University, College Station, TX
Professional Experience: 20 years

Mendez, Michael J.
Expertise: Infrared and gamma detectors and associated instrumentation; custom test-stand software
Education: B.S. in Physics, California Polytechnic State University, San Luis Obispo, CA
Professional Experience: 3 years

Moore, Eric T.
Expertise: High energy particle physics in heavy flavor physics, neural pattern recognition, radiation detection, data analysis, and gamma-ray spectroscopy
Education: Ph.D. in Particle Physics, University of New Mexico, Albuquerque, NM
Professional Experience: 1 year

Mukhopadhyay, Sanjoy
Expertise: Radiation sensor development, intermediate energy hadron physics, gamma-ray spectroscopy, neutron detection and energy measurement
Education: Ph.D. in Nuclear Physics, Northwestern University, Evanston, IL
Professional Experience: 13 years

Murphy, Luc Y.
Expertise: Radiation detectors systems, data acquisition, Monte-Carlo modeling and data analysis; medium to high energy nuclear physics with real and virtual photons: theory and experimentation; gamma ray spectroscopy, low energy neutron detection
Education: Ph.D. in Nuclear Physics, Rensselaer Polytechnic Institute, Troy NY
Professional Experience: 9 years

Noto, Heather M.
Expertise: Remote sensing, image processing and analysis, hydrogeology, applied geophysics
Education: M.S. in Geology, University of California, Riverside, CA
Professional Experience: 5 years

Noto, Robert C.
Expertise: Computer-related science including programming, hardware/software design, and administration; Geographic Information System sciences including analysis, customization, web development, and administration; geologic/geographic sciences including tectonics, sedimentology, structure, basin analysis, and geomorphology
Education: M.S. in Geology, University of Nevada Las Vegas, Las Vegas, NV
Professional Experience: 7 years

Parson, Bill
Expertise: Telecommunications, information systems, network and systems integration
Education: M.S. in Information Systems, University of Phoenix, Las Vegas, NV
Professional Experience: 28 years

Pollina, Richard J.
Expertise: Nuclear, chemical and biochemical sensors; nonproliferation signatures; technical and scientific imaging
Education: Ph.D. in Physics, Rutgers University, New Brunswick, NJ; Post-doctoral Research Associate (1970-1975), Massachusetts Institute of Technology, Cambridge, MA
Professional Experience: 31 years

Quam, William M.
Expertise: Passive and active detectors for gamma and neutron detection; special purpose LET counters for medical uses; very high dose instrumentation fuel storage tests; system architecture and data analysis for scintillators, HPGe detectors, CZT crystals and various proportional counter systems. Construction and fielding of ruggedized detectors and their software interfaces. Active infrared personnel scanning instrumentation.
Education: M.S. in Nuclear Engineering, Massachusetts Institute of Technology, Cambridge, MA
Awards, Recognition: Professional Engineer, Nuclear, State of California
Experience: 44 years

Rivera, Marc A.
Expertise: Aerial photography, photonavigation, integration and operation of aerial acquisition systems
Education: A.S. in Electronics Engineering, Clark County Community College, Las Vegas, NV
Professional Experience: 22 years

Schmidthuber, Eric J.
Expertise: Digital and analog electronics, embedded controller design and software development
Education: B.S. in Electrical Engineering, University of Nevada Las Vegas, Las Vegas, NV
Professional Experience: 17 years

Senh, Khy S.
Expertise: Analog and digital circuit design; QNX real-time programming, Assembly language
Education: B.S. in Electrical Engineering, University of Nevada, Reno, NV
Professional Experience: 20 years

Wagner, Eric C
Expertise: Nuclear engineering, health physics, gamma-ray spectroscopy, radiation detection, numerical radiation simulations.
Education: Ph.D. in Nuclear Engineering and Radiological Sciences, University of Michigan, Ann Arbor, MI
Certifications: Certified Health Physicist
Professional Experience: 4 years

Wu, Sherman S.C.

Expertise: Digital photogrammetry; radargrammetry; planetary mapping of Mars, the Moon, Venus and other planets
Education: Ph.D. in Civil Engineering, University of Arizona, Tucson, AZ; M.S. in Photogrammetry, Syracuse University, Syracuse, NY
Professional Experience: 52 years; published more than 130 technical papers
Awards: 1992 Fairchild Award from the American Society for Photogrammetry and Remote Sensing; Meritorious Service Medal from the U.S. Department of the Interior; Outstanding Alumnus of the Defense University of the Republic of China; newly discovered 2075 asteroid has been named Wu

Yuan, Ding

Expertise: Remote sensing, image and geospatial analysis, mathematics and statistics
Education: Ph.D. in Geological Remote Sensing, Syracuse University, Syracuse, NY; M.S. in Mathematics, Syracuse University, Syracuse, NY; M.S. in Geological Exploration, China University of Geoscience, Wuhan, Hubei, China
Professional Experience: 17 years

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Use all lower case.

Example:

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1.0 Radiation Exposure Rate Mapping

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1.1 Multi-Platform System

Kendall G. Braithwaite, Christopher J. Joines, Khy S. Senh, Ronald E. Guise
Remote Sensing Laboratory - Nellis

Background

The Multi-Platform System (MPS) is a mobile data collection system being developed for a range of applications, including aerial gamma data collection in support of emergency response missions. MPS uses technologies developed for previous systems and establishes a software and hardware architecture suited for future modification and enhancement.

Method

For emergency response operations, MPS consists of a single detector pod, an embedded acquisition system and a mountable user display personal computer (the Cabin display), Figure 1.1-1.

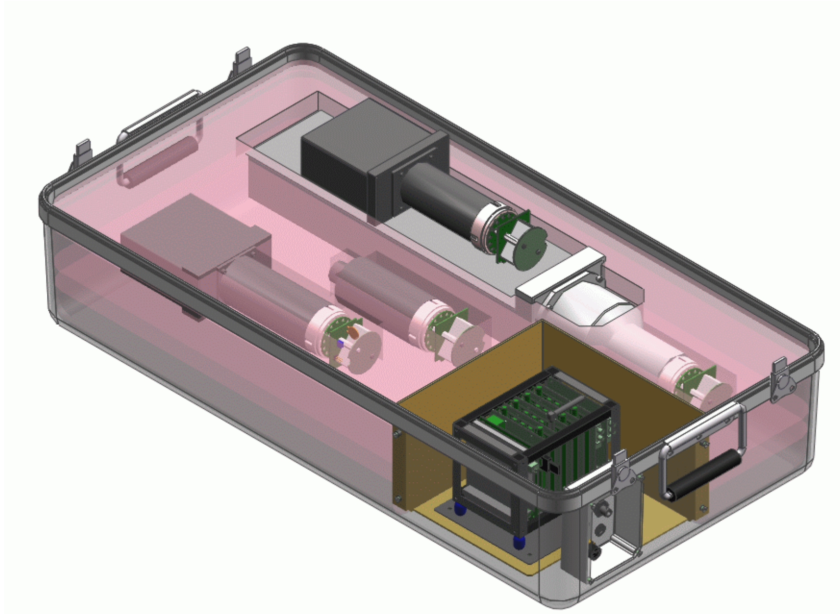

Figure 1.1-1. Multi-Platform System configured with four Na(Tl) detectors. The foam-filled case is 31.5” x 16.5” x 6” with a buckle-on lid 3.5” high.

The system provides count rate and spectral data acquisition and display for multiple sodium iodide (NaI[Tl]) detectors. For emergency response missions, the system is configured to provide count rate data from four NaI(Tl) detectors of three different sizes. The system will combine spectral and radar altitude data to provide a detailed isotope-specific mapping capability. An on-board display system allows real-time spectral display and track mapping.

The detector pod captures the spectra from four detectors. The preamplifiers include automatic gain control, which allows summing of the spectra and conversion from channel to energy. Four linear analog-to-digital converter (ADC) boards capture the spectral data, as well as live-time and dead-time data.

One or more pods connect to a central acquisition system by Ethernet. The acquisition system provides to the pods a once-per-second pulse that is delayed 0.5 seconds from the once-per-second pulse of the global positioning system (GPS). Acquisition software is being developed to log the ADC spectral data, altimeter data and GPS data at a continuous rate of once per second.

The Cabin system software provides live data display as well as count rate histograms to the operator.

Status

Prototype equipment has been assembled and will be bench tested when the software is ready. Testing will follow in vehicles and on the King Air B-200 (fixed wing) and/or the Bell 412 (helicopter) aircraft.

Conclusion

When completed, MPS will provide several new capabilities to the emergency response mission. These capabilities include spectral recording with reliable summing of several detectors and isotopic contour mapping.

1.2 Development of a New AMS Data Acquisition Device

Thane J. Hendricks, Eric T. Moore[1]*, Sanjoy Mukhopadhyay, Luc Y. Murphy*[1]
Remote Sensing Laboratory - Nellis

Background

The TI project to develop a new data acquisition system for AMS began in FY 2001. Although a great deal of progress has been made in reviewing the currently available technologies, certain aspects of the review process remain incomplete. This addendum proposes to complete those items and evaluate off-the-shelf equipment for use in a new data acquisition system. Currently AMS uses the Radiological Environmental Data Acquisition Recorder, Version 5 (REDAR V) system for detailed radiological surveys. Even though REDAR V is a highly developed consequence management asset, it remains bulky, power hungry and is a proprietary research data acquisition system used only by the U.S. Department of Energy. The front end of currently available REDAR V electronics is complex and needs experienced setup. In addition, REDAR V has some components that are either custom made or have become obsolete, and replacement parts are difficult to find.

Scope

The technical goal of this addendum is to experimentally study off-the-shelf equipment and suggest modifications for AMS data acquisition systems. The items studied are the microBASE multichannel analyzer (MCA) manufactured by Target GmbH in Germany (sold in the United States by Ortec Corporation) and the GR-660 manufactured by Exploranium G.S. Limited of Canada. A related system, the GR-460, a single, sodium iodide (NaI) log gamma spectrometer (also manufactured by Exploranium) was evaluated under the Special Project Instruments program. Results from the 460 laboratory and survey tests are just becoming available. Technical evaluation of the microBASE MCA is being carried on at RSL–Andrews.

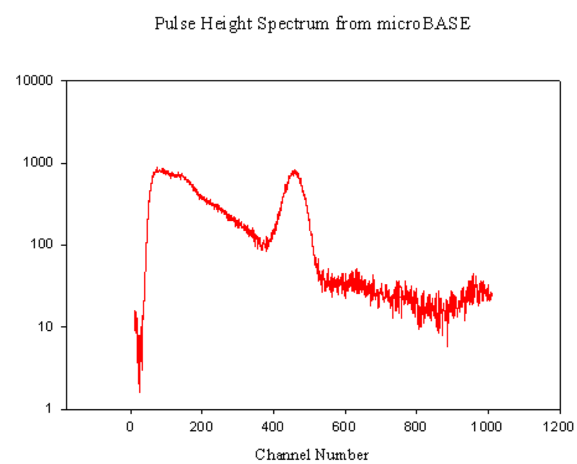

Figure 1.2-1. Pulse height spectrum with a microBASE

The microBASE includes the preamplifier, amplifier, detector high voltage and MCA – all in a compact, integrated module. Figure 1.2-1 shows a pulse height spectrum taken with a microBASE MCA. Figure 1.2-2 depicts the GR-660 system.

[1] Remote Sensing Laboratory – Andrews

Method

The GR-660 and GR-460 have been tested in the laboratory for normal and high count rate situations. Detailed data sets show the pileup effects and associated spectral distortions under high count rate conditions. Surveys near Nellis Air Force Base and at the Nevada Test Site will complete the test sequence for the Exploranium system.

Status

A comprehensive report has been written assessing AMS requirements for a consequence management data acquisition system (required sensitivity, spatial resolution, spectral resolution, count rates, etc.). In parallel, a survey of the current technology included site visits to selected laboratories to gain detailed information about modern data acquisition technology. These reports have been submitted to the AMS Project Office.

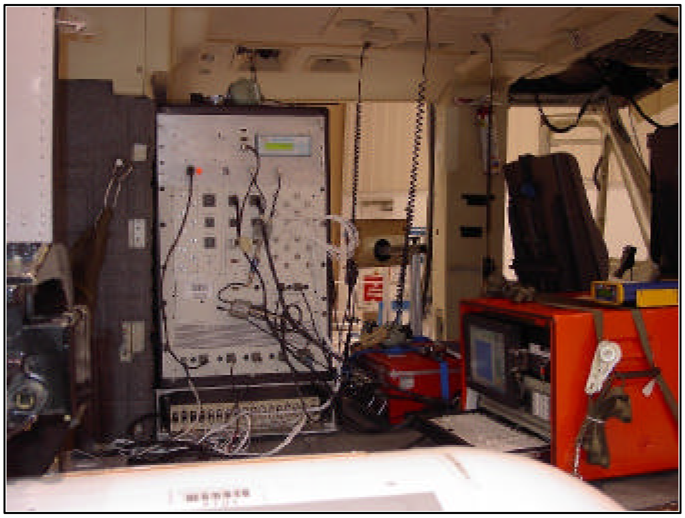

Figure 1.2-2. GR-660 and REDAR V on board a helicopter

The following Exploranium activities have been accomplished:

- Radar altimeter: The vendor has been contacted and is rewriting firmware to correct problems found with the GR-660 and GR-460 radar altimeter input.
- Differential global positioning system: (DGPS) hardware has been interfaced with the GR-660. Tests are in progress.
- Input routines have been developed to allow the full analysis capability of the PC REDAC (Radiation and Environmental Data Analyzer and Computer) to be applied to data from Exploranium systems.
- Pileup tests for the GR-460 have been completed and analyzed. Effective conversion time ranges from 13 – 34 µsec measuring from background count rates to high count rates and is comparable to the performance of the existing REDAR V.
- Exploranium GR-460 test flights are finished and analysis is nearly complete. Results are comparable to legacy REDAR V results when compared on the basis of an equal number of detectors.
- GR-660 test flights are complete and flight data are being analyzed.

Conclusion

The entire Emergency Response community is looking for commercial-off-the-shelf (COTS) sensors and data acquisition systems such as those studied here. This project evaluated the possibility of replacing REDAR V with a user-friendly Exploranium COTS system or an expanded version of the same. The microBASE appears to offer a COTS MCA that could be the basis of a replacement for the REDAR V system. The expandability of both systems must be carefully evaluated, as the Exploranium GR- 660 has only about one-third the sensitivity of the REDAR V.

2.0 Radiation Spectral Mapping

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2.1 Analog Front End

Thane J. Hendricks
Remote Sensing Laboratory – Nellis

Background

Photomultiplier tubes acquired in the last few years have shown unacceptable gain instabilities. To correct this problem, the Analog Front End (AFE) was developed for RSL by Paulus Engineering Company (PEC) to incorporate amplification, pulse conditioning and gain stabilization circuitry to interface standard sodium iodide detectors with spectral acquisition systems such as the Radiological Environmental Data Acquisition Recorder, Version 5 (REDAR V).

Experiment

RSL, in cooperation with PEC, developed the concept and specifications for the AFE. PEC designed and built a prototype which was tested extensively by RSL in laboratory and flight situations. RSL-suggested design enhancements were incorporated by PEC, followed by the production of three AFEs. Production units were thoroughly tested and have been incorporated as standard sub-systems in REDAR-based systems at RSL-Nellis. Figure 2.1-1 shows the AFE mounted in the REDAR V.

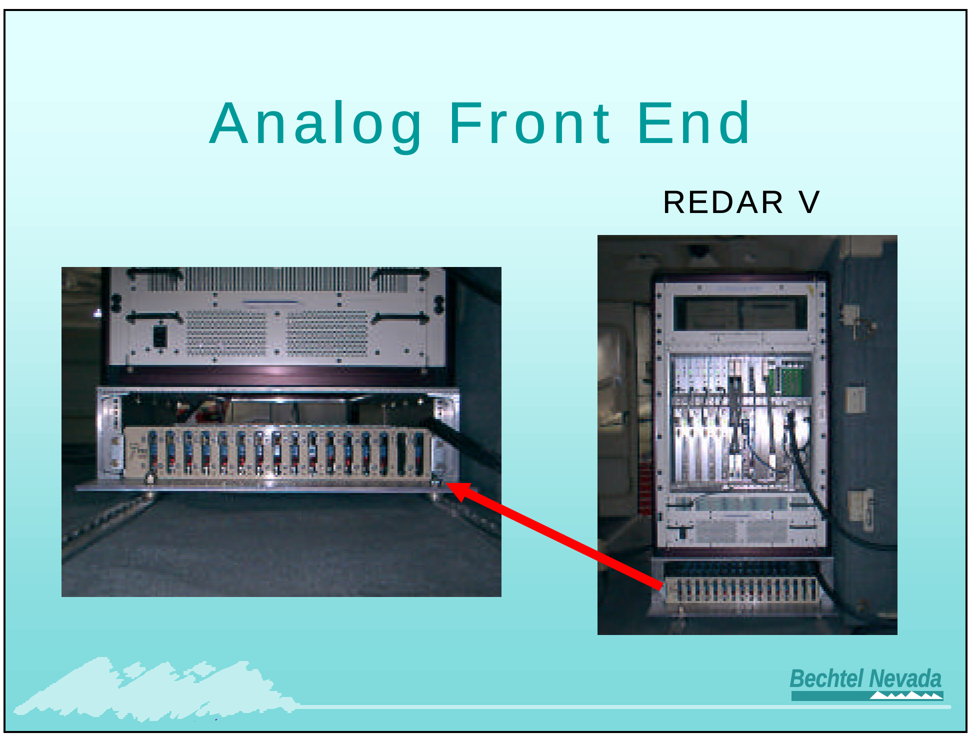


Figure 2.1-1. Analog front end (left) closeup, and mounted in the REDAR V (right)

Status

Additional AFE modules are being ordered to fill all 16 channels in each of the three production systems which have been delivered to RSL – Nellis. After the new modules are tested, one AFE system will be transferred to RSL – Andrews.

The development task has been completed. Production AFE systems have been incorporated into REDAR systems and successfully used on numerous proficiency flights at Government Wash and on aerial and Kiwi surveys at China Lake and at Area 8 of the Nevada Test Site.

The AMS task has been completed with two exceptions. Final documentation and schematics are being produced by PEC. Final RSL procedures have not been completed due to a cost model change. Draft procedures allowing interim setup and operation of the AFE have been produced and are being validated and rewritten.

Conclusion

This TI task led to the successful development and production of an advanced capability system that interfaces AMS sodium iodide detectors to REDAR and other nuclear data acquisition systems. The AFE produces cost savings by allowing less-stable detectors to be effectively used rather than replaced, improves data quality by stabilizing the recorded gamma spectrum and markedly reduces detector setup time in field survey activities.

2.2 Cadmium-Zinc-Telluride Gamma Detector Array

William M. Quam
Special Technologies Laboratory

Background

Cadmium-Zinc-Telluride (CZT) crystals are room-temperature, high-resolution gamma-ray detectors that can be bought off the shelf for use in medical imaging devices. Detectors with sufficient energy resolution to identify common medical isotopes, such as Iodine-131 (at 364 keV), can readily be designed and constructed without need for cooling. Of the two U.S. manufacturers, we have extensive experience with crystals from eV Products and more limited experience with crystals from Saint-Gobain (formerly Bicron).

Good energy resolution is the main reason for exploring applications of CZT. However, crystals are small, commonly 5-mm cubes. This small size severely limits the sensitivity (or detection efficiency); the 5-mm thickness limits the high-energy efficiency above 500 to 600 keV.

One method for overcoming the small size of individual crystals is to assemble many crystals into an array. Several 8-crystal arrays have been built, with resolution and efficiency improving over the years. This work describes the most recent design. The goal is to create an improved, 32-crystal array, several of which used in parallel would be suitable for vehicular applications.

Experimental Work

Among other applications, CZT spectrometers with better efficiency and improved energy resolution for sources of interest to AMS are being developed by exploring construction of large arrays. STL designed and constructed a 32-crystal array in FY 2001 using somewhat inferior analog electronics. In the analog electronics were improved significantly, the digital multiplexing scheme proven and the digital summation methods adapted successfully from the 20-crystal, high-purity germanium array of five years ago. The new 32-crystal array should be assembled early in FY 2003.

The array packaging was tested for temperature and shock. The 8-crystal design will receive slightly enhanced packaging early in FY 2003. The large, 32-crystal array uses four 8-crystal packages with a multiplexing scheme.

Results

8-Crystal Array

goals were resolution improvement, analog electronics improvement and minor redesign of the 8-crystal hardware. The resolution at 122 keV (from Cobalt-57) in previous designs suitable for field deployment varied from 6 to 7.5 % full width at half maximum (FWHM), depending upon the quality of the crystals. The current, field-usable design shows a resolution of slightly less than 3 % FWHM. The minimum detectable activity (MDA) is being calculated for this current array. The MDA calculations can be extrapolated to the 32-crystal array for planning purposes.

The resolution was improved by (1) enhanced analog electronics by use of a simpler personal computer (PC) board layout and electrical shielding between the four sections of the array and

(2) better selection of the crystals from eV Products. The high-voltage power supply, an integral part of each 8-crystal array, was mechanically modified in anticipation of miniaturization in FY 2003.

A small, hand-held spectrometer capable of identifying most common medical and industrial isotopes will be assembled. The isotope identification software has been evaluated using previous 8-crystal arrays and is expected to need only minor modifications for use with the improved energy resolution. This same software has been used with the existing 32-crystal array and is expected to exhibit better MDA values with the new analog hardware. Either of these software designs would be suitable for AMS vehicular-borne CZT arrays.

32-Crystal Array

The 32-crystal array, as presently configured, collects 16 separate spectra, one from each pair of CZT crystals. These spectra are automatically gain- and offset-corrected and digitally added together to produce one output spectrum, which provides isotope identification a few milliseconds after the collection ends. This same method of data collection and handling could be used for a super array of four or more 32-crystal arrays.

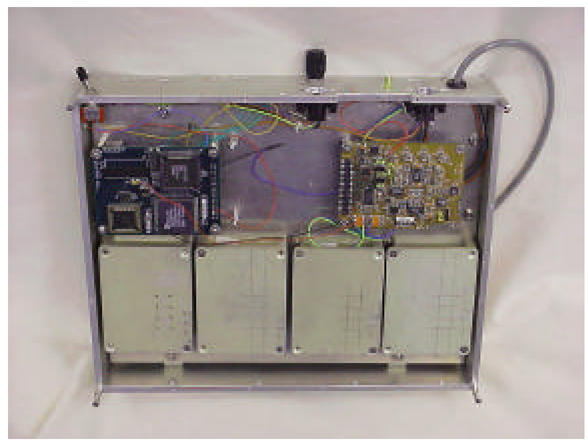


Figure 2.2-1. 32-crystal array

The 32-crystal array prototype is shown in Figure 2.2-1. The four gray boxes in the lower part of the instrument are identical 8-crystal arrays. The PC boards in the upper part of the instrument are the analog-to-digital converter board with multiplexer on the right and the central processing unit board which controls the entire instrument and processes the 16 individual spectra for isotope identification.

Conclusion

The current work at STL on CZT crystal arrays has produced significant improvement in energy resolution by incorporating better analog design. The Cobalt-57 resolution improved from 6% to 3% FWHM, enabling more accurate isotope identification with lower MDA values. The improved hardware has been used with existing high-voltage power supply designs with slight modifications, resulting in a field-ready, battery-operated instrument.

The current instrument contains eight crystals configured in pairs. The spectrometer acquires four separate spectra which are digitally added together to correct for gain and offset for each crystal pair. Isotope identification software uses the resulting spectrum for isotope assignment of the common medical and industrial isotopes.

In FY 2001, a 32-crystal array that uses four of the 8-crystal array modules was constructed. This array collects 16 separate spectra that are digitally summed and used for isotope identification. A hardware upgrade early in FY 2003 will produce an instrument suitable for many AMS vehicular applications.

2.3 Joule-Thomson Cooled HPGe Detectors

Michael J. Mendez, William M. Quam
Special Technologies Laboratory

Background

Joule-Thomson (JT)-cooled high-purity germanium (HPGe) detectors use high-pressure gas, usually argon, to maintain the germanium crystal at <100 K during operation. This low temperature ensures exceptional gamma-ray energy resolution, permitting accurate isotope identification.

The present task explored the use of mixed gases, argon plus a small amount of ethane, as the energy source for cooling. Literature references from the National Institute of Standards and Technology and the Jet Propulsion Laboratory show that the JT coefficient, essentially the cooling capacity, of a suitable gas mixture can be improved by as much as a factor of ten over the pure gas. If this effect can be shown to apply to our JT-HPGe detectors, we can expect to use either a lower gas pressure or operate for a longer time with a given amount of gas at a higher initial gas pressure, while maintaining the detector temperature.

The data acquired support the improved JT coefficient. The premixed gases were difficult to obtain, however. The gas mixture used thus far, argon plus 10 mol% ethane, is not a common commodity.

Experiment

The experimental work area was set up to allow safe operation with high-pressure gases. The JT-HPGe detectors were equipped with the newer, solenoid-operated JT coolers and had not been contaminated with pump oil from previous attempts. Seven of the eight detectors operated correctly on pure Argon.

Argon mixed with 10 mol% ethane was ordered from several suppliers, but delivery was obtained from only one. The gas mixture was supplied in standard gas bottles. Attempting to mix gas ourselves might have been more productive, given our experience. Additional gas mixtures have been ordered but have not arrived. It may be possible that improvements can be obtained for other simple gas mixtures with Argon.

Cooling performance was measured by digitizing the output of the internal platinum resistance thermometer attached to the germanium crystal inside the vacuum housing.

Results

We have shown that 2550 psi Argon plus 10 mol% ethane has essentially the same cooling capacity as pure Argon at 3100 psi. Figure 2.3-1 presents the first 30 minutes of data illustrating this effect. The cooling rate for the first 20 – 25 minutes is nearly the same for each gas tested. After 25 minutes, the gas pressure in the Argon + ethane mixture decreased enough that the initial cooling rate could not be sustained. The cooling rate was greater than 25 watts; the gas flow rate was greater than 20 liters per minute.

When the detector is at < 100 K, the cooling rate needed is only 2 watts at a gas flow rate of 2 liters per minute. This cooling capacity can be met by the gas mixture at a pressure of 2000 psi or less. We expect to verify this result by cooling with Argon and maintaining the temperature with the gas mixture.

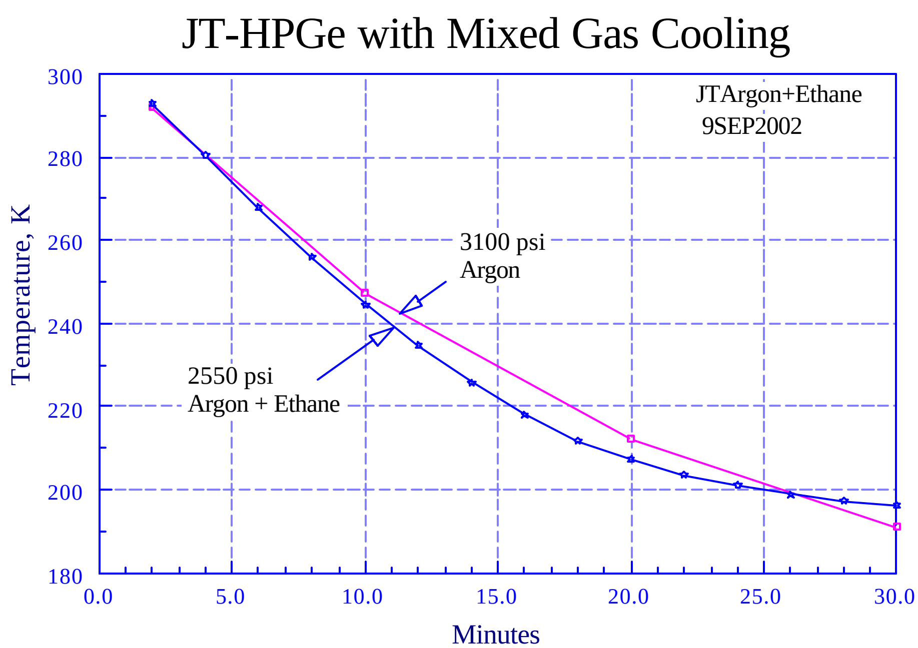


Figure 2.3-1. 2550 psi Argon plus 10 mol% ethane has essentially the same cooling capacity as pure Argon at 3100 psi.

Conclusions

The initial mixed gas data suggest that a similar cooling capacity exists for a gas pressure of about 25 % less than that needed for pure Argon. This result reduces the gas requirements for airborne use.

For field applications, it would be possible to cool an array with pure Argon and maintain the temperature with a gas mixture at a lower pressure. This dual-mode system would take advantage of the more readily-available pure Argon for initial cool-down.

Delivery of mixed gas has been a problem. In addition, the original vendor supplied the gas mixture labeled as flammable, the default position if no Factory Mutual test has been performed. We expect the gas mixture will have to be tested for flammability before any anticipated field use.

2.4 PC REDAC System

Paul J. Ainsworth, Clifton M. Bluitt, Thane J. Hendricks, Marnita A. Magner
Remote Sensing Laboratory - Nellis

Background

Aerial acquisition and analysis of radiological data is one of the AMS Radiation Science capabilities. The unique and powerful software, Radiation and Environmental Data Analyzer and Computer (REDAC), has evolved over the past twenty years to analyze the data from the Radiological Environmental Data Acquisition Recorder (REDAR), a specialized acquisition system built in-house. The basic PC REDAC application has been redesigned to run in a Windows 2000-based environment on a personal computer (PC). Written in MFC with C++, the application uses the Oracle 8i Personal Edition database for data storage. Many algorithms have been revised or corrected, resulting in an application that produces accurate, innovative results. Figure 2.4-1 and Figure 2.4-2 present preflight and postflight output created using the PC REDAC application.

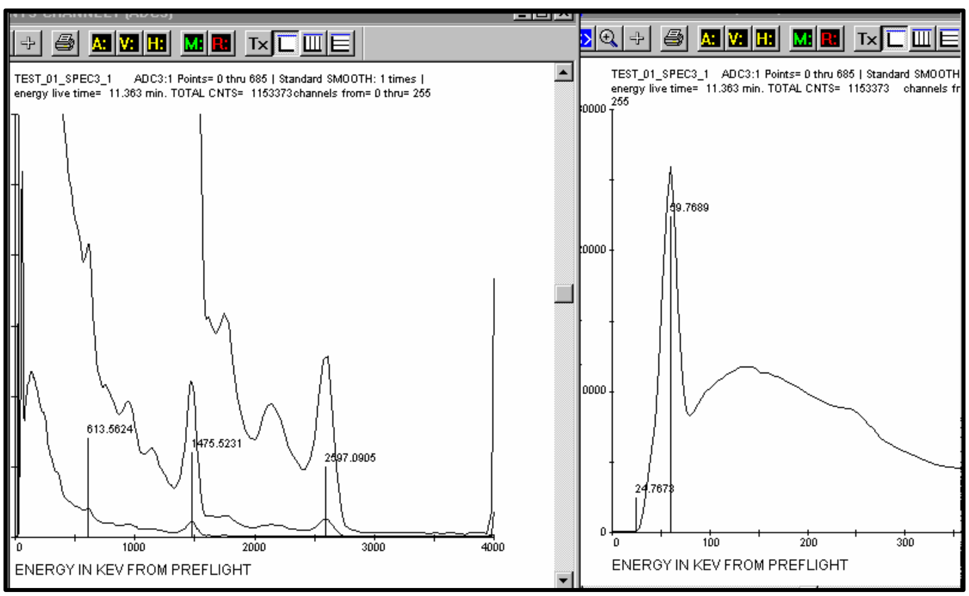


Figure 2.4-1. Preflight output from the PC REDAC. A preflight validates the acquisition equipment operations, detector collection capability and other calibrations. Note the buttons for annotation, printing, zoom in and zoom out and other options.

The PC REDAC software addresses spectral analysis algorithms, has a contouring package, gridding capability and a host of other utilities that enhance data processing. The user interface has been developed to ensure accurate and easy-to-edit lines, using interactive commands and running batches.

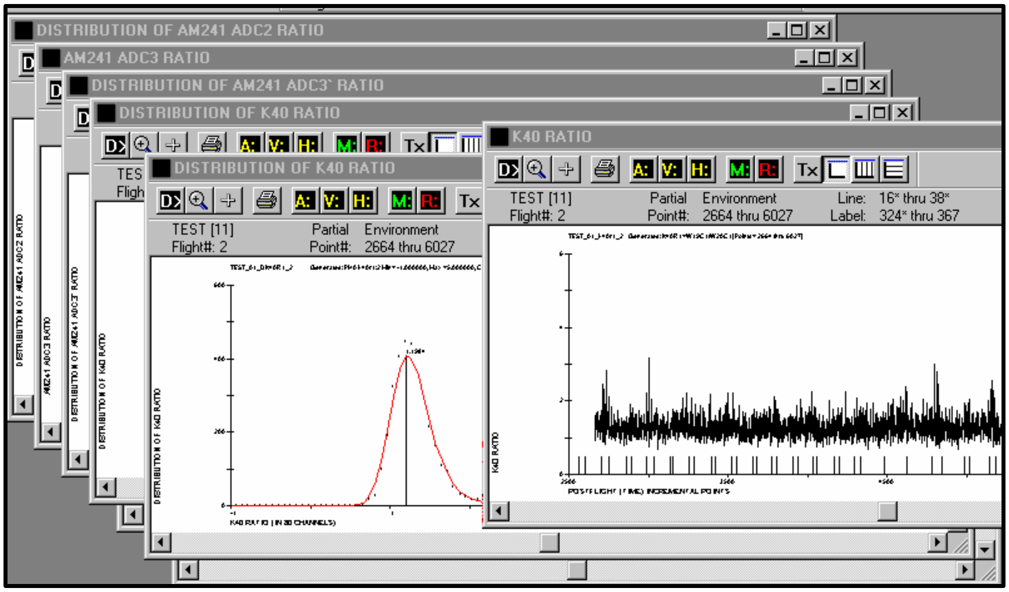


Figure 2.4-2. PC REDAC Plots from a post-flight batch. Plots are reviewed and adjustments in the algorithms, environment and plot scale can be performed. A Windows environment allows the export of results to other software packages.

Results

Version 1.0 of PC REDAC was released on April 1, 2001. Version 2.0 was released July 2, 2002 and version 3.0 was released on September 13, 2002. This most recent version of PC REDAC was designed to ensure that different data formats are easily accepted as program changes. It has a user-friendly interface and can write to a variety of standard printers and plotters as well as produce files ready for display in a geographical information system. As various data sets are acquired, new algorithms are continuously being developed and implemented by the in-house programmers.

Conclusion

Version 3.0 of PC REDAC is an analysis package that includes the latest computer technology. The application is easy to update and is written in a robust language for use on Windows platforms. Further releases will be made as needed.

2.5 National Calibration Standard

The Feasibility of the Creation of a National Standard for the Calibration of Gamma-Ray Detectors Used in Aerial Systems

Eric T. Moore
Remote Sensing Laboratory – Andrews

Background

Currently no national standard exists for the calibration of sodium iodide (NaI[Tl]) detectors for the detection of gamma-rays in airborne measuring systems. RSL has used its own calibration procedures within AMS for many years with a high degree of success. However, without a national standard the measurements might be questioned within the U.S. Department of Energy (DOE) and emergency response community or even dismissed entirely. A national calibration standard would alleviate that concern.

An International Atomic Energy Agency (IAEA) technical report on aerial surveys and calibrations is the standard for measurements outside the United States. It must be determined if an American standard is necessary or whether simply complying with the existing IAEA standard would be sufficient. If a distinct calibration standard is deemed necessary, that standard should, wherever possible, conform to existing standards or standard practices.

Method

RSL and the New Brunswick Laboratory (NBL) collaborated in discussions on the types of standards available and the approach to creating an American standard. Three types of standards were considered: 1) Development of an AMS calibration American National Standards Institute (ANSI) standard. The ANSI standard would be widely recognized outside the DOE and would be compatible with existing international standards. However, this rigorous, time-consuming procedure could take years to achieve. 2) DOE may require the less-rigorous DOE technical standard which would be easier and less time-consuming to achieve. 3) The International Organization for Standardization (ISO) standard is another, possibly less time-consuming standard.

The approach RSL and NBL developed for implementing a standard requires that NBL personnel participate in a complete AMS survey at one of the RSL facilities. NBL's experience in the creation of both DOE and ANSI standards would thus be enhanced in subsequent phases of the project. It should be noted that the IAEA has certain guidelines for the designation of an airborne calibration range. [Gra98]. Taken together, the required guidelines greatly limit the possible calibration ranges which might seriously be considered. Alternate calibration methods and possible procedural concerns are discussed in more detail in the full version of this report.

Status

Productive discussions between RSL and NBL indicate that further collaboration is very promising; both groups will continue to research existing calibration methods. NBL personnel will visit RSL to participate in an aerial survey in order to learn the procedures and to help clarify the need for a national standard. NBL will be responsible for determining and following the ANSI process and for contacting and demonstrating the need to establish a standard to the relevant ANSI committee, which may expect demonstrated compatibility with existing IAEA guidelines and standards.

RSL will be responsible for technical issues such as establishing the guidelines for the selection of calibration sites and establishing workable alternatives to calibration ranges. RSL will orient NBL personal to proper calibration procedures.

Conclusion

The goal of a standards process should be adoption of a broadly accepted standard such as ANSI or ISO. A DOE technical standard would be more quickly achieved than ANSI or ISO but would not have the breadth of acceptance.

The greatest possible guidance in the establishment of a workable American national standard should be sought by examination of existing standards, particularly those already established by the IAEA. [IAE91]. Adherence to accepted international practices will not only facilitate general acceptance of AMS results but will also facilitate ANSI committee acceptance of the desired standard, a process which might require several years. Although many benefits can be gained by meeting an existing international standard, some changes may be required to RSL internally accepted practices and procedures.

A national or international standard for AMS calibration is feasible. To facilitate the lengthy process, the following steps should be taken:

RSL should modify its calibration procedures to match IAEA guidelines.

NBL should determine the estimated time for adoption of an ANSI or ISO standard.

If the estimated time for adoption of an ANSI or ISO standard is as long as five years, a DOE technical standard should be established as an intermediate stage to the ANSI standard. The DOE process should not require more than one year.

[Gra98] R.L. Grasty *et al.*, *A Guide to the Technical Specifications for Airborne Gamma-ray Surveys*, Australian Geological Survey Organisation (1998).

[IAE91] IAEA, Technical Report Series No. **323**, “Airborne Gamma-ray Spectrometer Surveying,” International Atomic Energy Agency, Vienna, 1991.

2.6 FIDLER Pod Proof of Concept: New Initiative

Thane J Hendricks
Remote Sensing Laboratory - Nellis

Background

In weapons accidents that produce zero or very low yield, the predominant environmental contamination is Plutonium from the weapon. Presence of Plutonium in the environment is generally inferred by measuring 60 keV gamma rays from the daughter isotope Americium with sodium iodide (NaI) detectors.

FIDLER (Field Instrument for Detection of Low Energy Radiation) detectors were developed more than 30 years ago to measure low energy gamma rays. FIDLER detectors are designed with very thin (~1/16 inch) NaI crystals. High energy photons pass through the thin crystal with very little interaction (= low relative sensitivity), while low energy photons are essentially "stopped" (= high relative sensitivity) in the crystal. The thin crystal detector thus provides partial energy discrimination intended to improve detection capability for low energy gamma photons.

In the recommended FIDLER operation, the FIDLER operator makes a background measurement in an uncontaminated area very close to the suspected contaminated area or piece of debris, preferably within a few tens of feet. The Americium activity in the suspect area is estimated by simply subtracting the background activity from the activity measured in the suspect area.

For thicker detectors (2 to 4 inches) typically used for airborne applications, there is very little inherent sensitivity discrimination. For such applications, special spectral extraction techniques have been developed to measure Americium. The basic technique examines appropriate background energy regions of the spectrum on a second-by-second basis and uses the information to predict the amount of natural contribution in the spectral region where Americium should occur. The difference between the actual activity in the Americium window and the predicted activity is the net Americium activity.

This task addressed three bottom-line questions:

- How does the performance of a FIDLER array with its inherent discrimination compare to the performance of a "thick" detector with both arrays being analyzed by gross count techniques?
- Can FIDLER characteristics be further improved by spectral extraction techniques? How do FIDLER and log arrays compare using this technique?
- What are the capabilities and tradeoffs for using FIDLER and/or "thick" detector arrays in survey applications?

Experiment

Subtasks included in the task were to 1) acquire a minimum of ten FIDLER detectors, 2) characterize the FIDLER detectors for sensitivity vs supply voltage, 3) design, fabricate and test an interface which applies voltage, adjusts gain, extracts detector signals and applies signals to the Radiological Environmental Data Acquisition Recorder (REDAR) multiplexer, 4) modify a spare B412-compatible detector pod and install FIDLER detectors, 5) calibrate the FIDLER sub-system, 6) conduct source pull by experiments to characterize FIDLER array performance, 7) conduct flights over a background area (Government Wash), an Americium-only area (Plutonium Valley at the Nevada Test Site) and a mixed-isotope area (Area 8 at the Nevada Test Site) to compare FIDLER and standard detector performance in real field activities, 8) analyze data and 9) report data results.

Status

Sub-tasks 1 through 8 were completed before activities were suspended for funding reasons.

Results

While the FIDLER array outperforms the log array for constant background measurements, the highly variable background encountered in aerial and wide-area surface surveys makes this operation mode unusable.

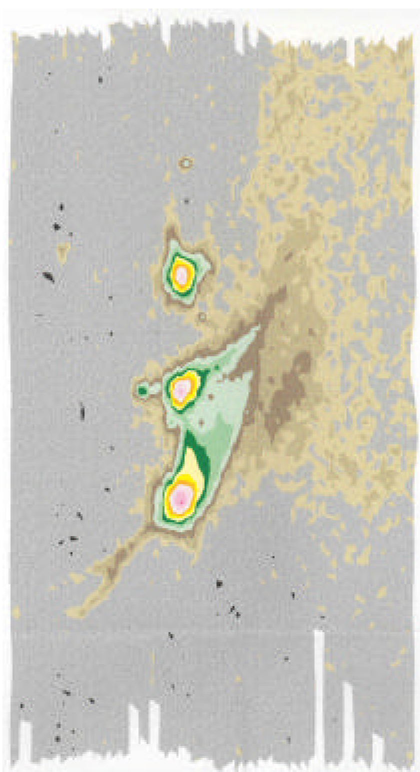
When spectral extraction techniques are applied (a technique allowing dynamic background removal), the performance of both the FIDLER and log arrays is superior to performance in the gross count mode. In the spectral extraction mode, the log array outperforms the FIDLER array.

The contour mapping results using spectral extraction verified that the FIDLER array did not give better results than the log array, see Figure 2.6-1.

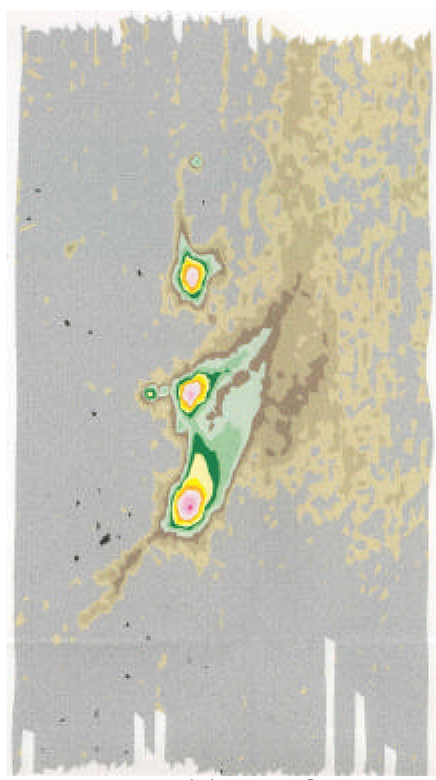
Because the FIDLER provides very little high energy spectral information, no improvement for low energy survey measurements and requires additional hardware to interface with the acquisition system, there does not appear to be any reason (compelling or otherwise) to pursue using a FIDLER array for extended area survey applications.

Acknowledgement

Special appreciation is extended to Jezabel Stampahar, whose data analysis support was invaluable



FIDLER Americium results



Log Americium results

Contour Color	Net Americium 6 Log Detectors* (cts per sec)
Black	< -90
Gray (+/- 3 sigma)	-90 ->90
Light Brown	90 -> 160
Medium Brown	160 -> 280
Brown	280 ->510
Light Green	510 ->900
Medium Green	900 -> 1600
Green	1600 -> 2800
Light yellow	2800 -> 5100
Yellow	5100 -> 9000
Orange	9000 -> 16000
Light Pink	16000 -> 28000
Pink	28000 -> 51000
Light Magenta	51000 -> 90000
Magenta	90000 -> 160000

* 10 FIDLER detector count rate = 0.9 x 6 log detector count rate

Figure 2.6-1. Differences between FIDLER and Log detector results are not statistically significant.

2.7 Fourth DREAMS Detector Module and Module Enhancement

Harvey W. Clark, Jr., David P. Colton
Remote Sensing Laboratory - Nellis

Background

For many years, only one B-200 was required to be flight ready and equipped with the airborne radiation computer system (ARCS) and DREAMS, a gamma detection pod. However after the September 11 disaster, both the Andrews- and Nellis-based aircraft were required to be on a four-hour departure standby. During the period when only one aircraft was on standby, there were three complete ARCS/DREAMS systems. One was assigned to each location; the third served as a spare. After the requirement for two aircraft to be on duty simultaneously, it was determined that a spare ARCS and DREAMS should be assigned to each location. A fourth ARCS was fabricated and delivered to RSL – Andrews, but no spare DREAMS.

Although the Incident Response mission no longer includes airborne air sampling, it does include plume tracking by circumnavigation of the plume at radiation levels just ten times background. However, if a release is on-going at the time the mission is conducted, it may be difficult, if not impossible, to discriminate between a weakly radioactive plume and heavy ground contamination. Therefore, the potential exists for inadvertent entry into the contaminated air mass, if the mission is planned to be near the projected plume trajectory. This is a serious safety matter, because the aircraft could be contaminated, which could both limit its utility and be costly to remediate. Crew dose is a minor concern, because significant levels of radiation are easily avoided away from the point of origin. Therefore, it was determined that instrumentation should be added to discriminate between being in a plume (contaminated air mass) and simply being over contaminated ground.

Method

This task addressed both providing the fourth DREAMS for RSL – Andrews and addition of an uplooking detector to be used as a qualitative indicator of a plume. The work consisted of 1) addition of an uplooking detector to the design, 2) fabrication of the fourth DREAMS, 3) software and hardware changes in ARCS to support the uplooking detector and 4) certain mechanical adjustments of all four DREAMS units to assure equivalence and ruggedness. The task concludes with recalibration of all four DREAMS pods.

The uplooking detector is a 4- x 4- x 2-inch thallium-activated sodium iodide (NaI[Tl]) scintillator, which is centered on top of the 4- x 16- x 2-inch detector. The two detectors are separated by a 10-inch-square graded shield made of a 0.25-inch lead sheet sandwiched between two 0.040-inch sheets of cadmium sheet. The Spare input to ARCS was modified to electronically match the other three inputs. Software was modified to add a Ratio mode to the existing Counts and Exposure Rate modes. The new Ratio mode computes and plots the ratio defined as:

$$\text{Ratio} = 1000 \times \frac{\text{Uplooking count rate}}{\text{4x16x2 count rate}}$$

Overflight of contaminated ground lowers the ratio. Immersion in contaminated air increases the ratio.

Status

All work is complete except for calibration of the new DREAMS. This task has been delayed, because the aircraft has not been available for such activity. The calibration will be scheduled in February.

Conclusion

The ARCS/DREAMS system with the newly added uplooking detector extends RSL's ability to detect airborne radioactivity. Unfortunately, a weak plume cannot be recognized by the system in the presence of strong ground concentration. It is recommended that a future TI project develop a window-open/window-closed Geiger-Mueller detector to directly measure airborne radioactivity. Ideally the detector would be external to the aircraft to minimize cost and complexity.

3.0 Modeling and Simulation

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3.1 Simulator for AMS Radiological Mapping Systems

Harvey W. Clark, Jr., Thane J. Hendricks, Eric J. Schmidthuber, Eric C. Wagner
Remote Sensing Laboratory - Nellis

Background

Training for AMS has traditionally depended upon the experience gained by frequent radiological surveys for environmental applications. However, it is impossible to find large areas of high-level contamination such as would result from a nuclear disaster. Even placement of large radioactive sources as targets for aerial searches has become difficult. As it became apparent that simulation was the key for more realistic training, the U.S. Department of Energy Headquarters encouraged an aggressive effort to develop a versatile tool that mimics the response of a detector immersed in a hypothetical radiological dispersal or near a hypothetical radioactive source.

The AMS Simulator is now used regularly by RSL - Nellis and RSL - Andrews for training and exercises. The Simulator has been used with the Radiological Environmental Data Acquisition Recorder (REDAR) and airborne radiation computer system (ARCS) on a variety of platforms including the B-200s, Bell 412s, P-3s and Kiwi (an aerial survey system mounted in a dedicated vehicle). Not only does it provide training value for the flight crew but also for the data analysis team. At this year's Joint Venture drill, flight crews observed the response – actually, the lack of response of ARCS and REDAR to the hypothetical plume footprint. The footprint was only revealed by proper post-flight analysis by the analysis team. The most novel application simulated flight crew exposure rates and cumulative dose for overflight of a nuclear detonation fallout field.

Method

The AMS Simulator is comprised of Field Airborne Radiological Measurement Simulator (FARMS) software and a specially designed hardware support platform. FARMS runs on any personal computer, but full functionality is only realized with the specialized hardware platform. FARMS computes the count rate expected for a sodium iodide (NaI) detector at a given position in a radiological scenario on a second-by-second basis. The detector's size can be chosen from a list of those commonly used by RSL. The count rate can be either gross or photopeak. Position can be input externally or generated internally for simulated flight of a pattern of uniformly spaced lines. The radiological scenario can be either an Atmospheric Release Advisory Capability (ARAC) prediction or a point source. The radiological material is characterized by the gamma activity as a function of energy. The gross count includes a crude estimate of number buildup using the dose buildup factors. Photopeak count rate is revealed by postflight gamma spectroscopy. Figure 3.1-1 shows a simulated search.

FARMS is augmented by UTM, a program that can translate, rotate and scale an ARAC prediction. That is, it can move the release point to a new location, change the plume orientation and rescale the magnitude of the source term. Thus a single model prediction can be reused without being recognized as a repetition, greatly reducing dependence on ARAC to run a model prediction for each training session.

The specialized platform, called the AMS Simulator, uses the count rate computed by FARMS to synthesize analog pulses identical to those output by a NaI detector. The specialized platform can obtain current position from either an external global positioning system (GPS) or from its own imbedded GPS. It can also recognize being over water, and then veto the output signal to avoid the appearance deposition on water. The Simulator's synthesized detector output is then summed with the actual detector signals. In this way, the data contain all the complexity of the terrain, plus the signature of a realistic, two-dimensional, hypothetical plume or deposition footprint.

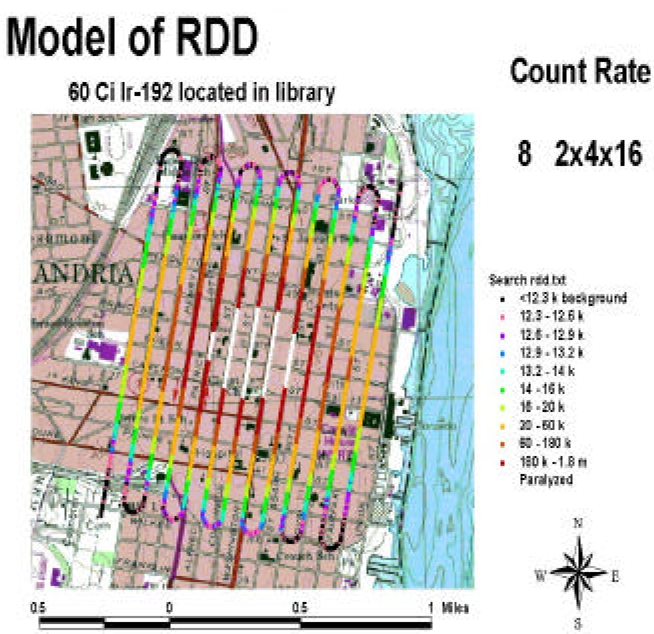

Figure 3.1-2. Simulator creates AMS data from hypothetical lost Iridium source search

Status

Each of the three AMS Simulators constructed was delivered with a library of eleven ready-to-use scenarios, UTM and instructions (two at RSL–Nellis, one at RSL–Andrews). User training was conducted at both Nellis and Andrews. A project to develop a palmtop-based version is underway for field monitors.

Not only are the AMS Simulators routinely used, but full fidelity AMS Incident Response training on U.S. Customs Service P-3s is often conducted without even using ARCS. A laptop running FARMS generates simulated ARCS telemetry data which is input to a second laptop that simulates ARCS by running ARCS software.

Conclusion

Continued enhancement of the simulation software and specialized hardware is strongly encouraged, particularly an addition of a second analog pulser network. The analog pulse synthesizer network only produces pulses of a single magnitude, which corresponds to the energy of the most prominent photopeak of interest. Presently, the pulse rate is either for photopeak or gross count rate. A second analog pulse synthesizer network would permit simultaneous output of both photopeak and gross count rates. That is, one network would output the photopeak count rate, while another, corresponding to a much lower energy, would output at the gross minus photopeak count rate. The eventual goal is to achieve full spectral output. A second pulser network will achieve more than enough fidelity for all but identification of anomalous photopeaks.

3.2 Atmospheric Correction of Daedalus ATM Data

Edwin L. Doak, Ding Yuan
Remote Sensing Laboratory - Nellis

Background

In FY 2001, numerous methods for atmospheric correction of RSL airborne multispectral scanner data were reviewed [Yua01]. Based on budget considerations, management adopted the least expensive option, implementing the German-developed commercial package ATCOR4 [Ric97] for RSL data. ATCOR4 software was chosen because it incorporates the response curve of the Daedalus 1268 ATM sensor. The current task was established to carry out this administrative decision.

The objective of the project is to implement a functional atmospheric correction system for AMS. We will identify and compare sources and schemes for gathering and deriving atmospheric parameters needed by ATCOR4 on the basis of readiness and accuracy.

ATCOR4 is not yet available in the American market; therefore, certain training and development may be needed.

The scope of the work includes (1) software acquisition, installation and testing; (2) atmospheric parameter selection, testing and assessment and (3) development of a supplemental user's manual. The project deliverable is a functional atmospheric correction module at RSL, along with a supplemental user's menu that emphasizes atmospheric parameter selections.

Experiment

Experiments designed for the project include (1) testing and evaluation for atmospheric parameters obtained from different sources, (2) visual assessment of the results of atmospheric correction and, if time permits, (3) quantitative assessment of the improvement of atmospheric correction.

Status

- October 2001 — ATCOR4 purchased
- July 2002 — ATCOR4 installed on server
  The time gap between software acquisition and installation was due to temporary suspension of the project.
- August 2002 — A small script was written and added to ENVI so that ATCOR4 can be launched from within the ENVI platform (Figure 3.2-1).

Because labor resources were allocated to other projects while the project was suspended, the software assessment and data processing experiments have been postponed to FY 2003.

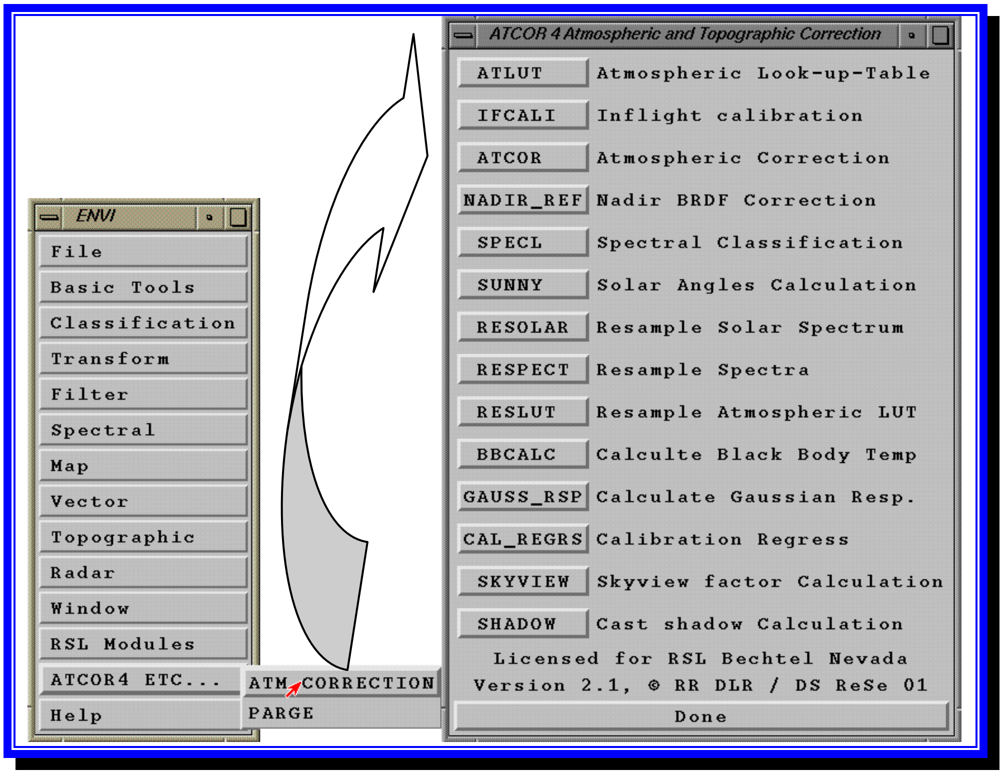

Figure 3.2-1. ATCOR4, now on the RSL server, can be launched from within the ENVI platform

Conclusion

Software acquisition and installation are complete. Software and algorithm assessment and data processing have been postponed to FY 2003 due to project interruption. The project will be completed and a report submitted in FY 2003.

References

[Ric97] R. Richter, "Correction of atmospheric and topographic effects for high spatial resolution satellite imagery," *Int. J. Remote Sensing* **18**:1099-1111 (1997).

[Yua01] D. Yuan and E. Doak, *Atmospheric Correction of Daedalus Multispectral Data: Model, Algorithm, and Options*, Bechtel Nevada Internal Report, July 2001.

3.3 Helicopter Detector Characterization

Rebecca S. Detwiler[1], *Peter C. Heimberg*, *Craig M. Marianno*
Remote Sensing Laboratory - Andrews

Background

In FY 2001, Monte Carlo N-Particle (MCNP) calculations were performed for the fixed-wing and helicopter detector packages. This work set up the code and provided initial data on the altitude-dependent spectral response. As input to the code, the detector arrays were characterized using small check sources in the laboratory. This arrangement was sufficient for single detectors at short distances but not for the large helicopter-pod detector arrays at altitudes more typical for search and survey scenarios.

The present characterization effort consists of both experimental measurements and computer modeling at intermediate distances on the order of one to a few attenuation lengths.

Experiment

Data were obtained for both source (1 mCi Cobalt-60) and background by hovering in the helicopter at various altitudes above the source. The flight pattern consisted of two distinct parts: (1) a "lateral scan" in which the helicopter hovered at several distances away from the source while maintaining a constant altitude and (2) a "vertical scan" in which the helicopter hovered directly above the source at altitude intervals corresponding to roughly 10% changes in scattered component. At each position, the helicopter hovered for approximately 1 – 2 minutes at constant altitude. Global positioning system information was recorded and will be used to correct for variations in detector-source and detector-ground distances.

Status

All data have been collected and an initial, rudimentary analysis indicates that the quality and quantity are sufficient to reliably constrain MCNP simulations. Some simulations using MCNP have been carried out at RSL – Nellis

Conclusion

A report describing the complete data reduction and comparison with MCNP calculations will be forthcoming in early FY 2003. A carryover of 320 hours will be requested to complete this project.

[1]RSL – Nellis

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3.4 Comparison of MDA Code and Experimental Data

John E. Mattson, Richard J. Maurer
Remote Sensing Laboratory - Andrews

Background

When performing or preparing for aerial surveys using helicopters or fixed-wing aircraft, one of the first tasks is to calculate the expected signal given the anticipated source activity, isotope and physical configuration. Then flight parameters such as altitude, velocity and line spacing are adjusted to match the mission. The code used to perform these calculations is the minimum detectable activity (MDA) code written by Richard J. Maurer. In a qualitative sense, the results from this code appear to agree reasonably well, provided one is only interested in the photopeak signal from the source. However, a quantitative comparison has not been documented. The primary goal of this work is to provide such a comparison.

In order to perform the experiment, we would have preferred to fly over many different sources with both aircraft. In fact, the original scope of work included such a plan. However, due to events of the past year, this project was put on hold and was only restarted in August. With the additional time restrictions, the scope of the work was significantly reduced so that the work could be completed in .

Experiment

The adjusted scope of work involved flying over two different sources with one aircraft, the Bell 400 helicopter. The sources were Cobalt-60 (^{60}Co) and Radium-226 (^{226}Ra) with activities of approximately 0.9 and 10 mCi, respectively. The Radium source has numerous daughter products, so the number of gamma rays produced is significantly higher than with pure ^{226}Ra.

Three different flight patterns were flown for each of the sources: (1) A source was placed in an open field near the end of the runway at Andrews Air Force Base. The helicopter flew a series of lines directly over the source at altitudes increasing from 100 to 1100 feet, (2) The helicopter hovered above the source at the same altitudes as in (1) and (3) Each flight contained a series of hovers in which, while maintaining a 150-foot altitude, the helicopter began directly above the source and then moved laterally in increments of approximately 100 feet. The hover portion (3) was also performed with no source present.

Status

We are presently in the final stages of analyzing the experimental data. Though detailed comparisons cannot yet be made between the MDA calculations and the experimental data, it is clear that the MDA code does not account for the low-energy buildup (Compton scattering) observed in spectra with increasing distance from a source. This low-energy buildup is a major contribution to the total number of counts observed, implying that when searching for a source an increase in total counts is the best indicator of the presence of a source. Looking for a specific peak in the spectrum is an inferior method for locating a source.

Conclusion

Until this work is completed, no conclusions can be drawn.

4.0 Photo and Spectral Imaging

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4.1 Assessment of Digital Photo Needs

Richard J. Pollina
Remote Sensing Laboratory - Nellis

Background

The *AMS Five-Year Plan* proposes the development of digital photographic imaging to create an entirely electronic photo acquisition process to enhance and modernize NNSA's remote sensing equipment for Incident Response. Fast turn-around images and a simplified photo acquisition process would permit easier transition to unmanned aerial vehicles and create user-friendly, modularized (roll-on roll-off) AMS capability. This study will address integration issues for program decision makers and provide information to assist in the future acquisition of digital cameras tailored to fit the Incident Response mission. The process involves research into the current digital camera technology to identify and understand both the advantages and the limitations of a technology. A mission imaging matrix was developed to express mission requirements for digital imaging technology *based upon current mission profiles.*

Based on the missions, cameras will be recommended which meet the requirements of broad applicability and telemetry potential. Because of rapid changes in current and emerging technologies, the study will point out those new developments which may be available now or which may be available soon. One goal is to explore the feasibility of providing a matrix of camera types showing their applicability to the matrix of mission needs.

Method

The digital photo assessment was performed as follows:

- The photographic requirements of current mission profiles were translated into digital imaging terms.
- The critical system functions for a digital camera and the characteristics of those functions which had to be considered in the decision process were detailed, along with a description of the critical system functions and characteristics, including their advantages and limitations.
- In order to direct this effort towards decision makers, it was assumed that the reader did not have prior experience with digital cameras.
- An effort was made to draw conclusions regarding the choice of camera(s) to support the AMS Program.

Results

This work began shortly after the September 11 disaster. Major delays in project completion were caused by the author's deployment on an emergency basis to support the U.S Department of Defense Joint Staff in the area of new technology implementation.

Photography in remote sensing is used as documentation to accompany acquisition by other sensors (*e.g.*, multispectral or radiological sensors), as photo documentation of an area (photos of environmental events such as fires), in the more precision modes of orthophoto and digital elevation model production and in photo interpretation. Therefore, the range of application stretches from the simple photo record to the complex color channel analysis of ground data – the earliest and simplest form of "multispectral" sensing using color, color infrared or filtered panchromatic film-based information. Cameras most often used for these acquisitions are Hasselblads, RC-30s and video (the latter is used in agricultural applications primarily). Digital cameras are defined in part by their sensor size (equivalent to film format) and in part by their feature set, just as film cameras are classified.

Table 4.1-1. Comparison of film and digital coverage and ground sample distance (pixel size)

Mission	Altitude (feet AGL)	Camera	Field of View (feet)	Ground Pixel Size
Film Mapping	8,000	RC-30, 6" lens	12,000	6.3"
Dig. Mapping	8,000	16Mpix, 24mm lens	12,000	3'
Dig. Mapping	4,000	16Mpix, 70mm lens	2,057	6.2"

Table 4.1-1 compares an 8,000-foot film acquisition of 12,000-foot swath width using the RC-30 camera with that of a 16-Mpixel digital camera replacing the RC-30. To keep the same swath width (*i.e.*, mission profile), the pixel size on the ground is six times that of the film pixel. If pixel size is important, then the example of a 4,000-foot acquisition (a different mission profile) is shown with the required pixel size. However, the swath width is one-sixth of the film swath; therefore approximately 36 digital exposures must be made to cover the ground with the same resolution as film at 8,000 feet. An 80–100-Mpixel camera would compare more favorably with film, but the cost would be 250 times that of the 16-Mpixel camera.

Conclusion

The digital camera domain brings a new set of issues based upon "conventional" specifications such as sensor size and frame rates, and on "unconventional" specifications such as color data processing, image file format, compression and burst rate. The goal to find a simple solution to conversion to digital image acquisition proves to be quite ambitious and very difficult to achieve. Digital camera technology is a young technology in a very rapid developmental phase, producing new and better devices at a rate faster than any survey of the technology could be completed. In addition, this report was not intended to be a complete survey of the technology. Second, as is apparent in this work, the digital camera is not a simple substitute for film technology. Film is a highly developed technology and has been a part of remote sensing since the beginning – or rather gave birth to remote sensing in the first balloon-based reconnaissance photo. Digital imaging acquisition technology cannot be inserted into the mature, finely tuned mission flight profiles currently flown without modifying the flight profiles. Therefore, incorporating digital cameras may mean changing the way data are acquired.

4.2 GENIE

Lynne M. Christel, Charles J. Golanics, Heather M. Noto
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Background

Image analysts at RSL continue their evaluation of the GENetic Imagery Exploitation software known as GENIE with its graphical user interface (GUI) named Aladdin. Developed at Los Alamos National Laboratory, GENIE is part of a continued effort by the Imagery Sciences Section to develop or acquire advanced data analysis and image processing tools. Results from the initial evaluation of GENIE in FY 2001 indicated that the classification accuracies achieved with the feature extraction software warranted a closer look at the software's capabilities with respect to RSL Incident Response (IR) and Consequence Management (CM) efforts.

The initial assessment of the GENIE beta-release version 0.99 focused on the evaluation of its classification accuracies and speed compared to six traditional classifiers provided by another image processing software package. In this second phase of the study, GENIE was evaluated in terms of the software's ease of use, ability to discriminate non-unique entities within and among scenes, and overall robustness. The latest GENIE beta-release version 0.99.6 was received in late July 2002 and installed on a desktop workstation with Red Hat Linux© version 7.1 as the operating system.

Method

This qualitative second phase of the GENIE evaluation focused on image training and exploitation results. Performance accuracy was based on analyst perception of the ability of the software was able to select application-specific features against the surrounding environment. Imagery considered relevant to the RSL's IR and CM applications was assessed for content in support of the evaluation criteria. GENIE's object-oriented algorithms de-emphasize the need for spectral information as they contribute other image feature characteristics such as texture, shape and size. For some applications, these operators were manipulated to include or exclude the multispectral operator.

Images were chosen based upon scene content; that is, imagery containing subject matter deemed pertinent to our criteria, with deliberate selection of images containing potentially confusing overlap of features both within and among scenes. The main applications considered were electronics, agriculture, forestry, hydrology, geology, military, environmental, energy and security. In Figure 4.2-1 GENIE successfully selected holes where objects had been buried as well as previously unknown post holes.

Results

- Improvements to the Aladdin GUI have cut back on the time required for analyst input.
- File management is somewhat confusing, and users must exit Aladdin every time there is a need

to change application or image, depending on file management style.

- When evoked from Aladdin, IDL(software)-based GENIE operations demanded approximately 99% of the central processing unit (CPU). Actual wall-clock times would need to be established for each of the scenarios before multiple sessions of Aladdin could be recommended when using the dual-CPU system for an IR or CM application.
- The number of parameters affecting the feature extraction process can be intimidating, but the developers have provided workable and informative defaults in lieu of lengthy explanations until a sensitivity analysis can be performed.

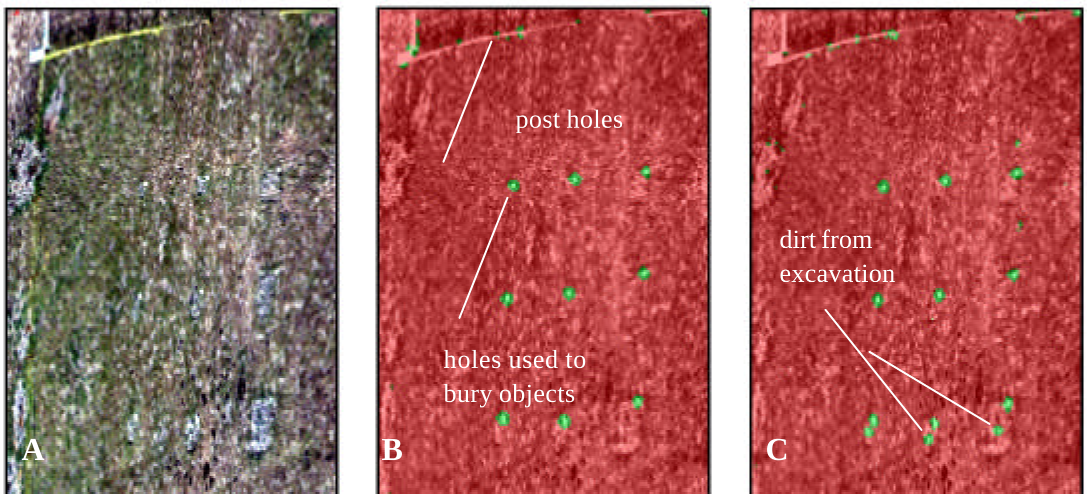

Figure 4.2-1. GENIE software searching for small, round shapes found holes used to bury small objects, previously unknown post holes and possibly dirt mounds from excavation. A - photo of area, B - best exploitation result, C - results after lowering the threshold

Conclusion

The main considerations for determining if GENIE is a viable tool from an IR and CM standpoint were software portability, ease of use (including timely performance) and output that can be easily incorporated into maps as geographically based information for use in a geographic information system. GENIE can reside on any processing platform that supports ENVI and IDL (software), and multiple processes can be run simultaneously without diminishing performance as long as multi-CPUs are available. The upgraded Aladdin interface has reduced analyst input time.

GENIE appears to have capabilities that would make it a good candidate for a wide variety of applications in which the objective is to locate one feature type in an image. If the GUI is expanded to support external image analysis, thereby eliminating the problem found in both beta releases of accessing necessary library files, the exploitation algorithm could be treated as an object-oriented feature in a lookup table in the same manner that is typically associated with spectral libraries. Analysts could produce lookup tables of object types for use in future applications to exploit imagery of the same genre as the training set. Continued communication with software developers regarding user needs and software development status is suggested and further evaluation of software releases is recommended.

4.3 Assessment of Integration of Hyperspectral Capabilities

Richard J. Pollina
Remote Sensing Laboratory - Nellis

Background

During the late 1970s through the mid 1980s, RSL possessed a unique capability for collecting multispectral imagery at very small ground sampling distance (GSD). Using its unique collection capability as a foundation, RSL developed and was able to obtain support for its image exploitation and geographic information system capabilities. An important advancement in capability was the development, under AMS funding, of the geometric correction and geocoding capability in the mid 1990s.

During the 1990s, hyperspectral imaging systems were developed and became operational. Although multispectral imaging did not then become obsolete, it was no longer cutting-edge. In an attempt to stay current, RSL made some unsuccessful efforts to acquire hyperspectral imaging capability. RSL cannot provide a competitive hyperspectral imaging collection and therefore also has limited staffing to perform credible exploitation of hyperspectral imagery. In order to remain competitive, RSL must assess and acquire hyperspectral capability.

Method

Very generally, the number of terrain categories and/or target materials that can be accurately identified via spectral exploitation is proportional to the number of spectral bands. The more classes that can be identified, the more applications there are for the collection system. Most existing and potential customers now desire the identification of specific materials, vegetation species and lithology that only hyperspectral can provide, rather than the very general classification possible with multispectral. Figure 4.3-1 shows some select applications for hyperspectral and the spectral/spatial requirements. The graphic also shows two planned government satellite systems, Coastal Ocean Imaging Spectrometer (COIS) and Warfighter (WF), and their place in the applications.

For RSL objectives, a hyperspectral imaging system is best categorized by the spectral regions in which it is sensitive: visible (VIS), near infrared (NIR), short wavelength infrared (SWIR), and thermal infrared (TIR). For some applications, the TIR may be subdivided into the mid-wavelength infrared (MWIR) and long wavelength infrared (LWIR). Reflectance is the phenomenology relied upon in the VIS, NIR and SWIR regions, while emission is the phenomenology for the TIR. In addition, the VIS-NIR is best suited for applications involving knowledge about identifying vegetation status and species. SWIR and TIR are best for identifying surface geology, lithology and most liquid and gas compounds. The cost of a hyperspectral imaging system is determined by the kind of detector used and by the method for separating the spectral bands. Detector costs increase with the wavelengths encompassed by the spectral region, as do methods for separating the wavelengths in the region, Fourier transforms being more expensive than dispersion but offering finer resolution.

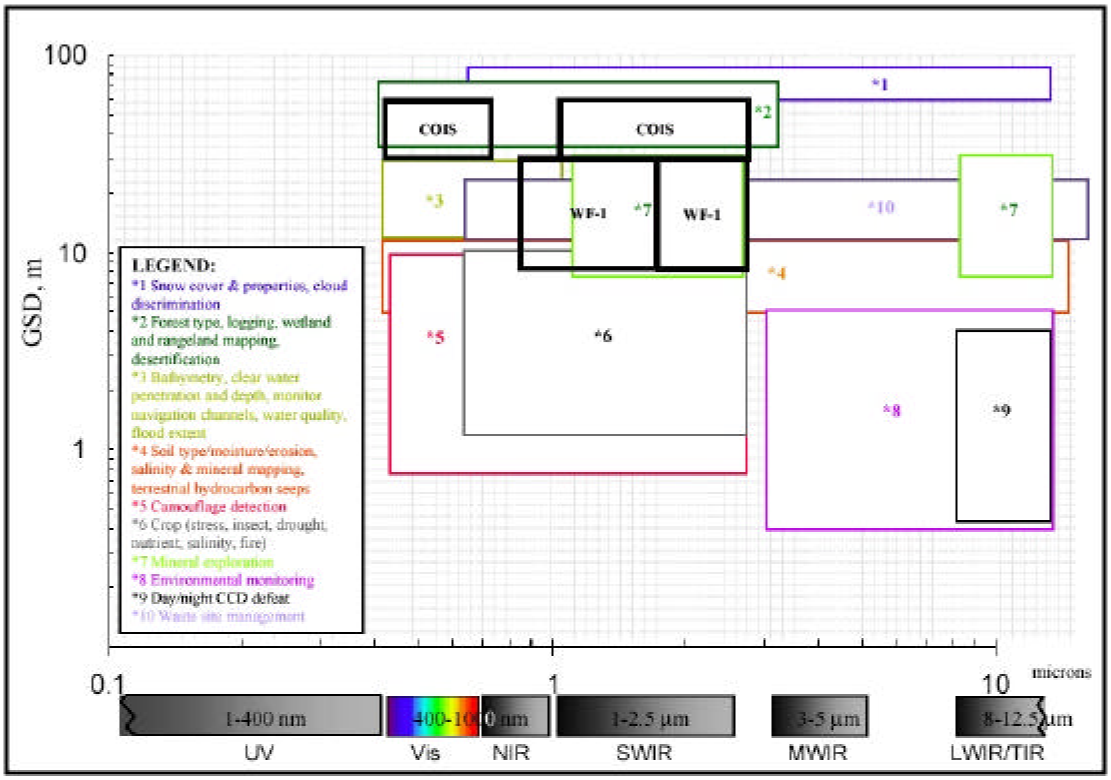

Figure 4.3-1. Hyperspectral imager applications and spectral/spatial requirements

Results

Commercial Hyperspectral Systems

A number of vendors offer hyperspectral imagers (HSI) for the VIS-NIR only, *e.g.*, CASI (manufactured by Itres), AISI (by SPECIM), and HyperCam (by Kestrel). The first two are dispersive systems, while the last is a Fourier Transform system. These systems cost in the neighborhood of $300K-$500K and can be considered “production” VIS-NIR systems. Other systems can be purchased, but should be considered custom or developmental.

The next step up in capability is those systems that collect in the VIS-NIR and SWIR regions, *i.e.*, the complete reflective regions of the spectrum. Costs are appreciably more: $2M-$3M, particularly if one requires all bands to have a common instantaneous field of view, or aperture, essential for accurate and efficient exploitation. The jump in cost over VIS-NIR is because the lower radiance in the region from about 1.0 to 2.5 microns requires more advanced detectors and optical systems. Some commercial VIS-NIR-SWIR systems are HyMap (manufactured by Integrated

Spectronics), MIVIS (by Sensytech), and EPS (by GER). Table 4.3-1 provides manufacturer's information on the more well-known commercial HSI systems.

Table 4.3-1. Specifications of commercial hyperspectral imaging systems

Manufacturer	Sensor	Cost ($US)	Spectral Range (µm)	Spectral Resolution (nm)	No. Bands
Sensytech	MIVIS	3M	VNIR 0.43–0.83 SWIR1 1.15–1.55 SWIR2 1.98–2.48 TIR 8.2–12.7	20 50 10 350	20 8 64 10
Integrated Spectronics	HyMap	2M	VNIR 0.45–0.89 NIR 0.89–1.35 SWIR1 1.40–1.80 SWIR2 1.95–2.48	15 15 15 15	126 bands total
Itres	CASI-2	500K	0.4–1.0	2	48–288
	new sensor	n/a	0.9–2.5	10	32–64
Kestrel	IrCam	n/a	1.7–5.0	45 cm^{-1}	55
	HyperCam	400K	0.45–1.05	87 cm^{-1}	256 (180 useful)
GER	EPS-A	1.5M	VNIR 4.0–1.0 SWIR1 1.5–1.8 SWIR2 2.1–2.4 TIR 8.0–12.0	0.4–1.05	28 1 1 1–4
	EPS-H	3M	VNIR 4.3–1.05 SWIR1 1.5–1.8 SWIR2 2.0–2.5 MWIR 3.0–5.0 TIR 8.7–12.3	8 50 16 0.67 600	76 16 32 3 6

At the present time, there are no hyperspectral imaging systems for the TIR. These imaging systems are in either the research or development phase.

R&D Hyperspectral Systems

While research and development (R&D) continues on better VIS-NIR HSI systems, the commercial systems are adequate for current needs in this spectral region, since exploitation is clutter limited. A need exists for operational systems with approximately 100 bands or more in the SWIR for geologic and soil pollution application. Two examples of R&D HSIs are the Naval Research Laboratory's HYDICE (210 bands spanning the regions from 0.4 to 2.4 microns) and TRW's TRWIS (335 bands spanning the regions from 0.37 to 2.33 microns). The latter, however, covers the spectrum with two sub-systems that do not have a common aperture.

HSI systems for the TIR are also in the R&D phase. Examples are Aerospace's SEBASS (128 bands for the MWIR and 128 bands for the LWIR) and the U.S. Department of Energy's HIRIS for the LWIR.

Conclusion

For approximately the last seven years, RSL's uniqueness/niche has been collecting sub-meter, geometrically corrected and geocoded multispectral imagery. Unfortunately, this niche is being infringed upon more and more as others acquire the same ability.

The move in spectral technology is toward hyperspectral imaging because of the amount of detailed information that can be extracted from such data. Therefore, to stand out from the crowd, RSL's new niche should be in the collection of sub-meter, geometrically corrected and geocoded hyperspectral/spectral imagery. To make it simple: without HSI, there is no growth in spectral business in the future. In order to improve its capability, RSL needs to move as soon as possible towards making operational its multispectral imagery-HSI transitional system, which is the 50-band modification to the DS-1268. Since the optical system is already in house, the digitizing and recording part of the system remains to be acquired. The investment of about $500K-$600K for the digitizing and recording component would serve RSL well for about five to seven years. The investment also should, with proper marketing of the capability, provide projects yielding, conservatively, at least $400K-$500K per annum for data collection.

4.4 Digital Photogrammetric Mapping

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Background

As part of the TI effort within the AMS Program, the development of an automated, on-board, real-time digital mapping system will provide RSL with the capability of rapid support of emergency response. The Digital Photogrammetric Mapping project in FY 2001 was a feasibility study for the development of such an automated real-time photogrammetric mapping system. In FY 2001, the project performed three tasks: digital frame cameras, Light Detection and Ranging (LIDAR) mapping systems, and the InterFerometer Synthetic Aperture Radar (IFSAR) mapping capability. The carryover project into of the Digital Photogrammetric Mapping project consisted of two parts: 1) further evaluate post-processed LIDAR data and present research results at a professional conference and 2) organize a meeting on digital cameras at RSL.

Method

LIDAR Data Evaluation

Post-processed LIDAR data acquired in FY 2001 were evaluated in by comparing products of LIDAR with ground truth from the National Imagery and Mapping Agency (NIMA) calibration range. Both discrete points and digital elevation model (DEM) data collected and processed from the ALTM 1225 system were compared with ground control points and DEM data from the NIMA's 15-square-kilometer calibration range at the Nevada Test Site (NTS). DEM data from LIDAR are both high resolution (300-m flight height) and low resolution (2000-m flight height). A detailed description of the evaluation and results was presented at the American Society for Photogrammetry and Remote Sensing (ASPRS) in St. Petersburg, Florida, October 2002 [Wu02].

Digital Camera Meeting

On August 8–9, 2002, a meeting on Digital Camera and Digital Mapping was held at RSL. Attendees by invitation only included J. Ginanni from U.S. Department of Energy, National Nuclear Security Administration; D. Miceli from the U.S. Air Force; G. Lee, K. Osborn and M. Liszewski from U.S. Geological Survey (USGS); B Gorin and F. Casano from the Fairchild Corporation; and eight scientists and managers from Bechtel Nevada (BN). In addition to presentation of papers, a tour of RSL was conducted for visitors. Attendees visited the NTS to assess the NIMA calibration range and the Geometric Correction System (GCS) calibration range.

Results

LIDAR Data

Results of the evaluation of LIDAR's discrete points indicate a measurement precision of standard errors ranging form 10 to 13 cm, whereas the LIDAR DEM data indicate a measurement precision ranging from 13 to 16 cm. More information on LIDAR measurement precision can be found in the paper presented at the ASPRS Florida Conference [Wu02].

Digital Camera Meeting

The meeting on digital camera and digital mapping held at RSL is considered significant. Highlights of the meeting include:

- Presentation of the Air Force C-26 program, which mainly involves the Fairchild 9k x 9k digital frame camera. RSL is interested in acquiring this camera.
- Detailed description of the 9k x 9k DFC presented by Fairchild Corporation.
- Presentation by USGS of the USGS-National Aeronautics and Space Administration (NASA) digital camera calibration program.
- National Digital Elevation Program presented by USGS.
- Presentation by BN of the ongoing development of a near real-time photogrammetric mapping system. The presentation yielded an invitation to present this paper at the NIMA Real-Time Mapping Workshop in Washington, D.C.
- Other presentations and tours by BN to present the scientific and technical capabilities at the RSL.
- Tour to the NTS for the assessment of the NIMA and GCS calibration ranges interested the U.S. Air Force in the USGS-NASA digital calibration program.
- The most significant aspect of the meeting was perhaps the proposal to organize an interagency Workgroup of Real-Time Geo-Intelligence.

Conclusion

Digital mapping is the new technical trend in the mapping world. A digital frame camera is the first step in the development of a real-time photogrammetric mapping system. In the high-resolution, high-precision DEM field, LIDAR is a new mapping tool. LIDAR can not only produce high-resolution and high-precision DEMs quickly but can also collect ground control points for mapping at low cost. The unique features of a LIDAR system include processing DEMs with bare surface (with vegetation removed), mapping during the day and at night and mapping without ground control points. LIDAR saves time, saves money and is a tool of great potential within the mapping community.

[Wu02] S.S.C. Wu *et al.*, "Evaluation of LIDAR Mapping Capability," Proceedings, American Society for Photogrammetry and Remote Sensing, St. Petersburg, Florida, October 2002.

4.5 Fast Turn-around Digital Imagery Products for Unmanned Aerial Vehicle Applications

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Background

The AMS program maintains the capability to fulfill a wide range of radiological and spectral airborne remote sensing missions. Fundamental to many of the AMS data products is the production of aerial photos, orthophotos, photo mosaics and digital elevation maps (DEMs). The DEM/Orthophoto products can be the basis for a customer deliverable with better visualization and three-dimensional display of the incident location and associated data.

One of the major requests in any emergency response mission is the delivery of preliminary data products within a short time from the initial deployment. Turn-around time can be reduced using digital systems whose data can be down-linked and analyzed in the required time frame. In addition, the AMS program is currently evaluating the requirements for the possible transitioning of some capabilities to unmanned aerial vehicle (UAV) platforms which require lightweight, low-cost (expendable) data acquisition hardware. It was desirable to demonstrate some data products using a relatively low-cost digital camera suitable for use on a UAV. To see the quality of product that would result from using freely available satellite imagery (ASTER), a mosaic of the Nevada Test Site (NTS) and a DEM were produced.

Method

To meet the objective of demonstrating digitally acquired imagery for fast incident response products, aerial photographs, orthophotos, photo mosaics and DEMs were chosen as the measure of capability. It was felt that these covered the full gamut, easy to hard, of typical products. An orthophoto is an aerial photograph that has been manipulated in order to reduce distortions from camera tilt and terrain relief. The result is an image with the same geometric integrity as a map. Image or photo mosaicking is a technique whereby multiple remotely sensed images, acquired by satellite or airborne platforms, are digitally joined. Generally the geometry and radiometry of the images are corrected for a seamless appearance. A DEM is simply a digital representation of terrain elevations for ground positions at regularly spaced intervals. Each pixel in a raster, or grid, image represents an elevation value.

The imagery used for this study was acquired with a Kodak DCS 330 camera. The photographs were taken on board a fixed-wing platform. One of the main interests of this study was to demonstrate the capabilities and accuracy of a relatively low-end aerial camera and its ability to create an accurate DEM as well as aerial photos and orthophotos.

Results

Imagery collected over a calibrated area was used to determine the accuracy of a DEM generated from the Kodak DCS 330 system. In July 2002, the Cessna Citation was flown over the Nevada Test Site's (NTS's) geometric correction system (GCS) grid, a calibrated site with 10-ft^2 markers placed over evenly spaced intervals and surveyed with a highly accurate global positioning system. The photographs were taken with a 20-mm focal length lens at a flying height of 3000 ft. Figure 4.5-1 is one frame of a series of stereopairs of photographs collected and processed for this study.

OrthoEngine v. 8.2, a georeferencing and mosaicking module part of the Geomatica image processing suite, was the tool used to generate the geometrically corrected images from the stereopair of air photos and was also used to create the DEM. Other vendors' ortho engines had not been released to the public yet.

In order to produce a geometrically correct and georeferenced image, ground features of known horizontal and vertical position must be identified. These points are known as ground control points (GCPs). Each of the nine GCS ground markers was used as a GCP. Tie points, features or points located in two or more overlapping images used to "tie" the images together, were also collected to help with the georeferencing process. Tie points are features of unknown location strictly used to aid in processing. After the stereopair of air photos was geometrically corrected, a DEM was created. The final, georeferenced DEM is shown in Figure 4.5-2.

Figure 4.5-1. Image acquired using the Kodak DCS 330 camera showing all nine geometric correction system markers

Elevation values range from 929.0 meters, represented by dark green pixels, to 962.0 meters, represented by light green pixels. These elevation values are based on the WGS 84 datum.

Conclusion

A statistics report summarizes the accuracy of the DEM. Results show that an root mean square error of 2.5 meters was calculated. The average error was determined to be 1.7 meters while the maximum error is reported to be 4.4 meters. The RMS error is a little larger than the maximum residual error of the GCPs, an outstanding result. As a result, the mathematical model properly describes the stereo-viewing geometry and is stable and robust for the full stereo-model without generating local or systematic errors.

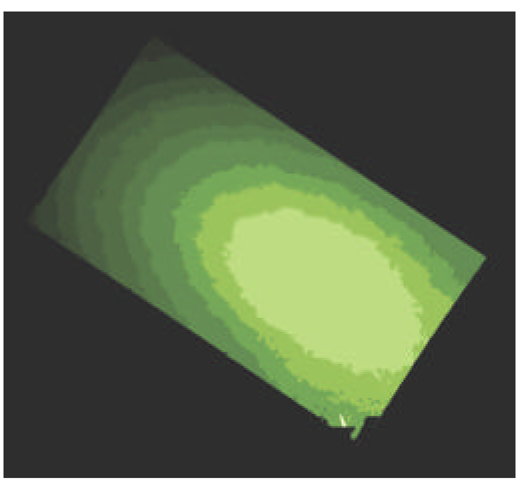

Figure 4.5-2. Georeferenced DEM where each color gradation equals 0.5 meters

In summary, the DEM produced from the simple camera used was very close in accuracy to that of the control points used for its creation. The three MPixel cameras on a UAV would be an excellent tool for flying aerial photos and producing the types of data products discussed here. To be sure, the area of coverage does not begin to approach that of the 9-inch mapping camera and would require at least a factor of ten increase in images needed to cover a large area. Since this project was begun, the cost per pixel for a digital camera has dropped by a factor of two or more, and 5–6 MPixel cameras are now common.

5.0 Data Telemetry and Networking

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5.1 Data Archival and Retrieval System

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Background

The U.S. Department of Energy (DOE) Headquarters has funded the Air Force Research Laboratory (AFRL) to develop its prototype Data Archival and Retrieval System (DARS) Lite to support the AMS Operational Mission and other Consequence Management capabilities. AFRL will use RSL's Geographic Information System (GIS) data in the initial stage of prototype development.

The DARS distributed system will support metadata cataloging and digital archiving of radiological measurements, imagery, geographic information (maps) and other technical information for the readiness phases of emergency response programs. RSL will use DARS to provide emergency response support (timely storage, retrieval and dissemination of products), aid the U.S. DOE National Nuclear Security Administration Headquarters and its Laboratories in the timeliness of data and other products, consolidate the RSL data into an integrated library archive, eliminate reliance on a few key individuals, reduce the size of response teams deployed to the field and provide support to litigation actions. In DARS, the user queries the database to locate an appropriate image, as in Figure 5.1-1.

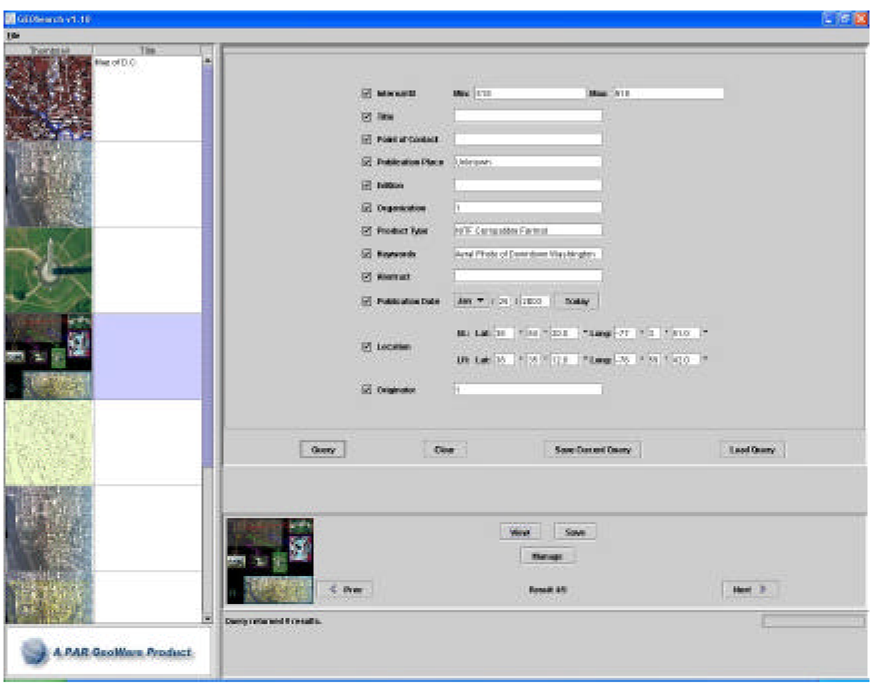

Figure 5.1-1. DARS database query returned several images. The image highlighted in purple was selected for review.

That image can be enhanced to provide information useful for emergency management, as in Figure 5.1-2.

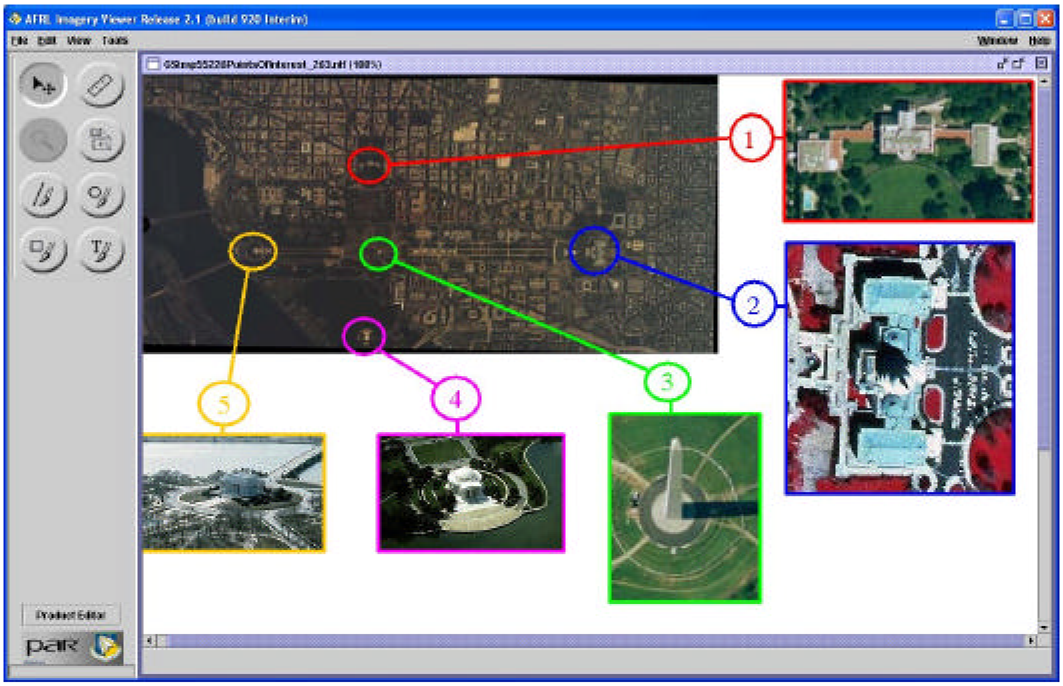

Figure 5.1-2. From the selected image, a composite product is created for decision makers.

Method

RSL provided technical collaboration to AFRL to assist in the development of DARS Lite. Face-to-face meetings were held in Las Vegas and at AFRL to review progress and provide technical input.

Result

AFRL has completed a majority of the project which is projected for delivery in December. The completed package includes a robust computer system, the DARS software on compact disk and a User Manual.

Conclusion

The sharing of data at RSL will soon be greatly improved. Intended primarily for geospatial data with GIS application, DARS nevertheless has the capacity to store all types of metadata. Users from across the facility will be able to input and access DARS from their workstations.

5.2 Telemetry for ARCS – RSL-Andrews B-200

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Background

Telemetry for the airborne radiation computer system (ARCS) was developed in FY 2001, but implementation was limited to the Nellis-based B-200 and the telemetry was not appropriate for routine emergency response operations. Goals for the effort were two-fold: 1) add telemetry capability to Andrews B-200 aircraft and 2) establish a permanent user downlink workstation for routine emergency response operations. The completed work is summarized in this paper.

In 1998, CalQuest satellite communicators were installed on the Andrews- and Nellis-based B-200s (N185XP – November 1998, N6451D – January 1998) to provide continental voice and fax communications for command and control for emergency response missions. The CalQuest was the fastest and most adaptable system approved for aviation applications at that time. When telemetry was proposed in fall 1999, it was recognized that a serial data channel would need to be added. A market study of communication options was conducted as part of the first TI project. The best course was addition of another channel to the existing CalQuest units. No higher-speed communicators were approved for aviation use nor were the antennas small enough for the B-200. The lower-speed Iridium system was not a candidate, because the company was bankrupt and de-orbit of the satellite constellation was a possibility. The second channel was added to N185XP in March 2001. Modification of the ARCS software began in July 2000 and was finalized by August 2001. Prototype telemetry capability was demonstrated at the Nevada Test Site in September 2001.

Method

The final operational implementation of telemetry was again demonstrated as part of the AMS TI program review in summer 2001 at the Kanab plateau. At that meeting, the decision was made to proceed with both implementation on N6451D and the downlink workstation in . This project added the second channel to N6451D in September 2002. Prior to the addition, Iridium was reconsidered. The cost estimate for slower Iridium was essentially the same as for augmentation of the existing CalQuest. Simultaneously, a workstation with adequate telephone and Internet connectivity was prepared.

Status

The AMS Incident Response telemetry downlink workstation, located in the Operations – Home Team Support Room at RSL – Nellis in Las Vegas, is depicted in the Figure 5.2-1. The workstation permits the Home Team scientist to simultaneously access the mapping data from two aircraft in real time. The data links are established by the Home Team scientist and are entirely transparent to the aircrews. The ground-based viewing application is the same application running in the aircraft for acquisition and display. Therefore, the Home Team scientist can view, adjust and manipulate the data just as if onboard but still independently from actions in the aircraft. This capability permits fine tuning of the data and enhancement of the mapping before delivery to users.

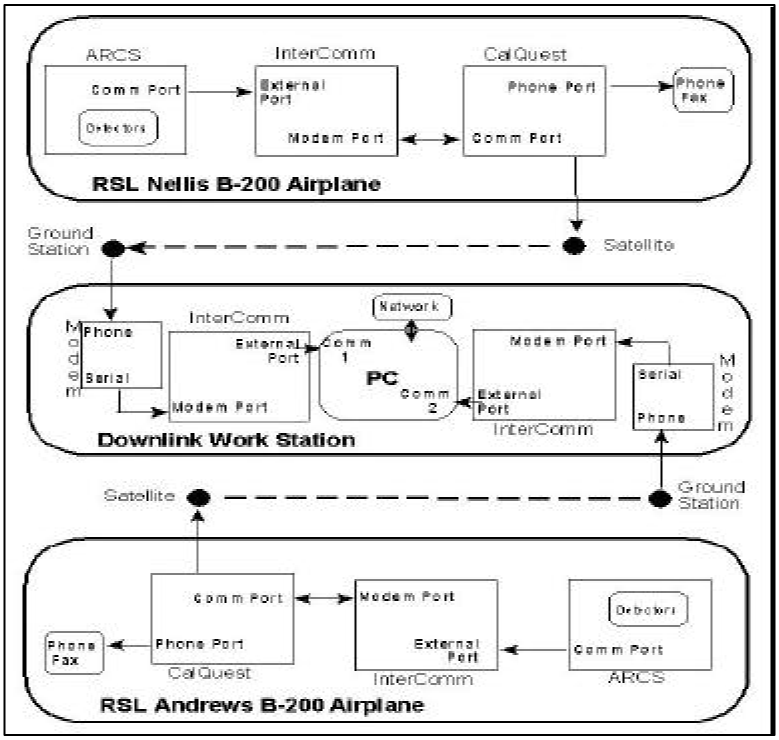

Figure 5.2-1. Diagrammatic representation of the entire telemetry train, including downlink workstation

The downlink work-station has two data presentation options. Trivially, at any instant during the flight, the operator can simply perform a screen capture of the live map being plotted by the ARCS 2 application. This can be instantly e-mailed to authorized recipients in a Microsoft Word document with comments. However, the preferred option is to export the processed data to a Geographic Information System (GIS) application for creation of presentation-quality graphics. GIS graphics are strongly preferred and promoted, because the base map or photo can be tailored to reflect the boundaries for protective actions, such as evacuation, sheltering or food embargo. Color-code break points for display of the AMS exposure rate data can be selected to correspond to Derived Response Levels for Protective Action Guidelines. Model predictions can be plotted with the AMS data with matching break points for easy comparison. Informative legends and descriptions can be imbedded. But most importantly, data from multiple flights (or acquisition sessions) can be combined on a single figure. Finally, a recent test demonstrated that the live ARCS display can also be viewed via the Emergency Communications Network.

Conclusion

Telemetry capability was added to Andrews B-200 aircraft and a permanent user downlink workstation was established for routine emergency response operations. The work is now complete and the capability is available for use.

5.3 Mission Assessment of NNSA'S Telemetry Options and Roadmap

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Background

Political changes across the globe have resulted in increased terrorist threats to U.S. interests and even to the U.S. homeland. To effectively combat these threats in an environment where technology is continually changing the risk and tempo of the threat, AMS resources require the ability to rapidly collect sensor data associated with potential or actual nuclear threats or events, and then transport that data as rapidly as possible for scientific analysis and timely exploitation by decision makers. Limitations in AMS telemetry have been a barrier to fulfilling the wide range of AMS requirements required by the U.S. Department of Energy, National Nuclear Security Administration (NNSA). The goal of the current project was to explore the range of options available to implement telemetry in support of AMS missions.

Method

A baseline was created of existing sensor systems used at RSL in support of AMS and other missions. Existing communications systems were catalogued for evaluation as potential carriers for telemetry products. This information was transferred into a matrix that details the technical parameters of the products.

Open-source materials were researched to identify the range of commercial off-the-shelf products that could be used to meet AMS requirements. Visits were made to several corporations that support the U.S. military with telemetry products in order to determine the viability of using existing commercial or military products. Compression algorithms were explored to determine if significant advantage could be achieved through existing or emerging technologies.

Status

A roadmap, Figure 5.3-1, was developed for implementing AMS telemetry at RSL. The roadmap recommends an incremental approach, beginning with completion of the current project to place CALQUEST satellite phones and modems on each of the fixed-wing aircraft. Costs, project complexity and emerging technology parameters span a fifteen-year period. Order-of-magnitude cost estimates were developed for the various telemetry and sensor recommendations.

The proposed roadmap recommends the use of satellite technologies to meet AMS telemetry requirements. Although the U.S. military has experienced great success in using aircraft-to-aircraft or aircraft-to-ground telemetry links, these concepts require significant logistical and personnel commitments. The reduction in forward deployed personnel required by the *AMS Five-Year Plan* causes these methods to be unworkable for AMS.

Conclusion

The proposed AMS roadmap provides a means for NNSA to incrementally provide significant advances in AMS mission support by implementing telemetry using currently available technologies that can span the continental United States and even meet requirements for operations outside the continental United States. Proposals for wideband and ultra-wideband telemetry systems appear in later years on the roadmap in order to allow NNSA to reprioritize existing funding or request additional resources from Congress. Throughout the roadmap, the establishment of partnerships between NNSA, the U.S. Department of Defense and other federal departments is a continual theme as a means of controlling costs and implementing an integrated systems approach. The inclusion of major sensor requirements underscores the link between the sensor and telemetry aspects of the AMS missions, each driving the requirements and limitations of the other.

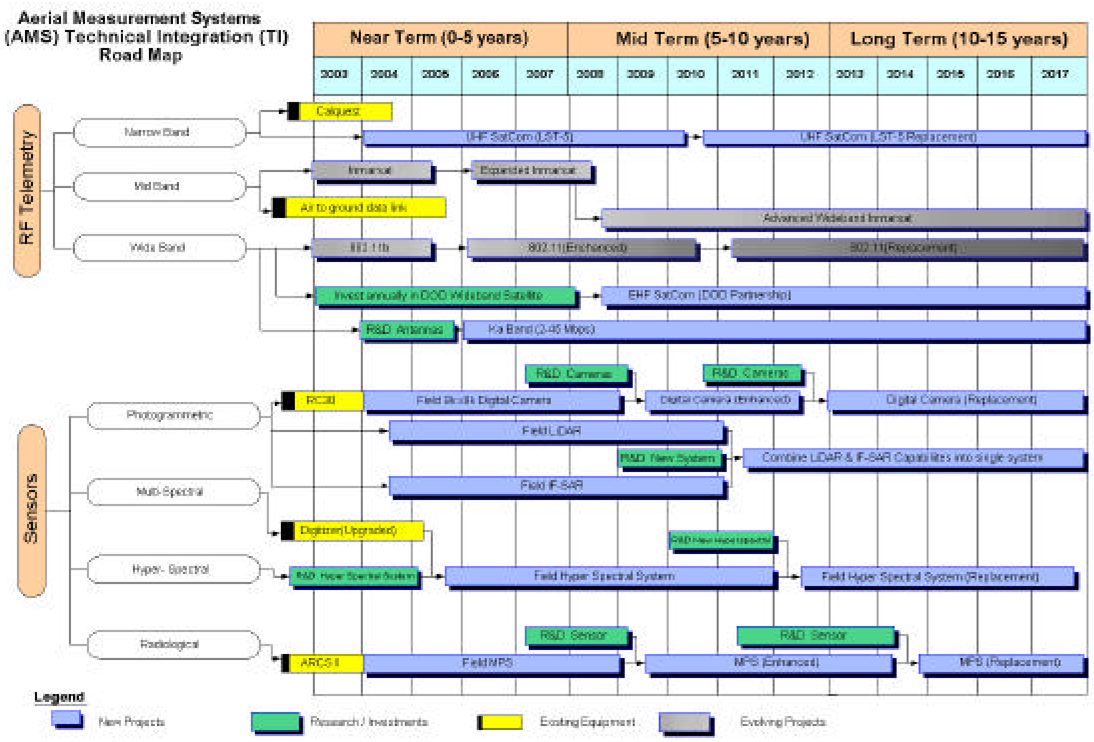

Figure 5.3-1. Roadmap for implementing AMS telemetry goals at RSL

5.4 Steganography and Digital Watermarking

Adam C. Chu, Carol A. Hyman, Robert C. Noto

Background

Steganography is the process by which one piece of information and is hidden within another. Computer files such as images, sounds recordings and even disks contain unused or insignificant areas of data. Steganography takes advantage of these areas, replacing them with information (encrypted mail, for instance). The files can then be exchanged without anyone's knowing what actually lies inside. Steganography can also be used to place a hidden "trademark" in images, music and software, a technique referred to as watermarking.

Method

A basic evaluation was undertaken of the SecureStego software package for geographic information systems (GIS) provided by the Air Force Research Laboratory in Rome, New York. Various forms of imagery, photography and raster products common to AMS applications were used to determine the viability for AMS missions. Each of the encryption methods and watermarking techniques was examined and tested.

The aims of the testing were to embed 1) images within images and 2) text messages within images. The image in Figure 5.4-1, with imbedded annotation, was encrypted to appear benign. The image could be sent over normal lines of communication without attracting attention. The image received by the intended recipient would be decrypted, revealing the annotation, as seen in Figure 5.4-2.

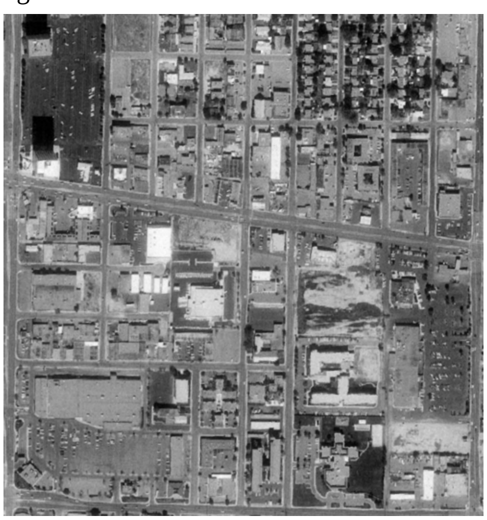

Figure 5.4-1. Encrypted image with imbedded annotation appears benign

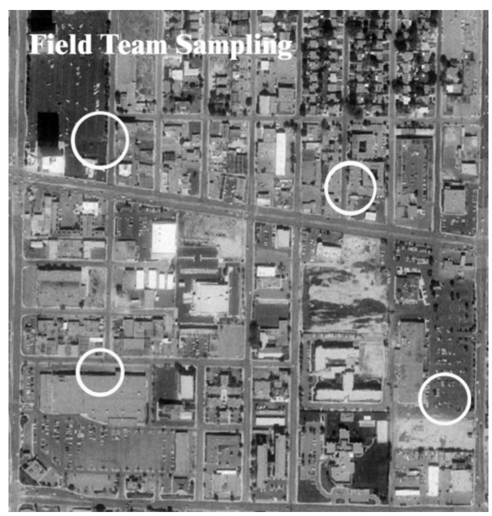

Figure 5.4-2. Decrypted image reveals annotation

Status

SecureStego testing did not produce definitive results. The primary purpose was to investigate the software and determine if, in fact, there might be an application for both GIS and AMS. A more current version of SecureStego was said to be available, but no update was received. The update may have eliminated many of the problems encountered during testing. The process of using SecureStego in the field could be very time consuming.

Conclusion

AMS may be able to benefit from watermarking and steganography software for GIS systems, which offers the ability to encrypt and transmit images containing coordinates, plots, metadata and text files via ftp; files attached to e-mail; floppy, Zip or Jazz disks; or compact disks. Watermarking would permit scientists to embed plots and maps with a digital signature. The watermark would provide an easy method to identify and categorize items before storage. Steganography gives scientists the ability to hide specific site identification information produced in the field prior to transmission of data. The user would determine the quantity of information to be hidden and the degree of security.

Although the SecureStego requires additional testing, the software package appears promising. Potential users will need to be thoroughly trained.

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