

# Survey & Cartography Session Abstracts

from

## NSS Conventions

This file contains the abstracts for presentations in the Survey & Cartography and related sessions at National Speleological Society conventions. The abstracts are in year order. The file is searchable.

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Prepared by Bob Hoke and Bob Thrun

Last revised on September 13, 2016

**1963 NSS CONVENTION ABSTRACTS**  
*(Mountain Lake, Virginia)*

**A Mapping Technique for Maze Caves,  
Developed in Anvil Cave, Alabama**

William W. Varnedoe

In the course of mapping Anvil Cave, Alabama, the Huntsville Grotto of the National Speleological Society evolved a technique for rapidly mapping large areas of this maze pattern cave. Using this technique about 13 miles of Anvil Cave have been plotted.

**1969 NSS CONVENTION ABSTRACTS**  
*(Lovell, Wyoming)*

**Data Retrieval and Cave Files**

W. W. Varnedore, Jr.

The sheer mass of data in state cave survey files and the NSS cave files makes finding a specific piece of information a formidable task. A technique of encoding the data to compress it and of using automation to order it for specific indices is presented.

**ASCDIF – A Proposed American Standard  
Cave Data Input Format**

Robert G. Babb II

Motivation is presented for establishing an American standard format for key-punching Brunton survey data. One possible data acquisition system is proposed. The system consists of a survey form for recording the data and a variety of standard program cards for key-punching data from the form. If the system gains acceptance, the author offers to write standard input routines in ASA FORTRAN and Algol so that a minimum of re-programming of existing survey programs would be necessary to convert them to accept ASCDIF.

**SPELEOMAP V and VI, Cave Mapping  
Programs**

Charles A. Plantz and Victor A. Schmidt

These two programs take raw survey data, compute the coordinates of the stations, and plot a skeleton map of the cave on a Calcomp plotter. A corrected version of the map, in which all closure errors are corrected by a least squares procedure, is also computed and plotted. Speleomap VI, which will hopefully be debugged by convention time, includes advanced plotting features and the ability to take survey sight data cards in any order.

**Ordered Loop Systems and Associated  
Error Minimization of Brunton Cave  
Survey by Computer**

James M. Hardy

This paper will discuss an algorithm for obtaining minimum loop systems and their associated line networks in undirected line topologies. It will cover the resulting error analysis found in actual Brunton cave surveys. A system for minimizing the resultant error by varying the base loops will also be presented.

**Keytape Systems and their Possible Effect  
on the Proposed Cave File Formats**

M. J. Stupak

This report is in no ways a recommendation for any proposed format or tape system. It is merely a report on the advancement of the state of the art and its possible effects on the present and proposed systems.

**1970 NSS CONVENTION ABSTRACTS**  
*(State College, Pennsylvania)*

**What Ought a Cave Map to Show?**

James Hedges

Published cave maps often contain so little detail that they are of slight use to persons not familiar with the caves shown. Only a little more effort would be required to clothe passage outlines with geographic, geologic, biologic, and meteorologic

data basic to the work of many specialists. Draughtsmen (and map users) often are hampered by the lack of enough commonly accepted symbols which adequately portray the significant features of caves. A revised, expanded list of cave map symbols is offered to supplant the NSS Standard Map Symbols of 1961. Even the most detailed cave map will not be an effective vehicle of communication if it is cluttered, cramped, or lettered poorly or is in other ways offensive to the eye. Cave cartographers should strive to produce maps which convey information in a graceful manner.

### **The Laser as a Cave-Surveying Instrument**

Frank S. Reid and Richard J. Blenz

Preliminary tests having indicated the usefulness of a small helium-neon laser in several cave surveying applications, a cave-portable system has been designed. The laser adapts readily to leveling and plane table operations, solving problems encountered when look-through optical instruments are used in a dark environment. The laser beam's brilliance and non-divergence make it extremely useful in making sightings at very long range. With the addition of mirrors and other simple parts, angle-measuring devices and a parallax-type range finder can be built. The problems of cost, bulk, and power supply are expected to diminish with the advancement of laser technology.

### **Determining Longitude and Latitude of Cave Locations by Computer Methods**

Ernst H. Kastning

Often the longitude and latitude of cave entrances are tabulated as part of a regional survey of caves. These coordinates are usually determined by reading them on a USGS topographic survey map upon which the cave location has been marked. Since the topo sheets are not graduated in seconds of arc, each location must be determined with either a specially scaled ruler or by mathematical computation.

A method which eliminates the tedium of hand calculation is presented here and is easily applicable to computer data processing. Human errors are thereby minimized. Inputs to the program are the topo sheet series (7.5-, 15-, 30-minute, etc.), the coordinates in degrees, minutes and seconds for the

lower left corner of the sheet, and the physical dimensions of the topographic map (i.e., the width at the top and bottom of the map and its height). For each cave an identification number, distances of the cave location from the left and bottom margins of the map and an estimate of an accuracy tolerance are fed into the program as input data.

Each topographic map is treated as a trapezoid and coordinates in degrees, minutes, and seconds are calculated based on this geometry. Batch processing will print out a list of the caves and their coordinates for each topographic sheet requested.

## ***1974 NSS CONVENTION ABSTRACTS (Decorah, Iowa)***

### **Computer Programs for Cave Survey**

Robert Thrun

Computer programs for reducing cave survey data. The state of the art is emphasized, avoiding mechanical details. Topics will be: type of computer, size of program, kinds of input data, methods of detecting closures, methods of processing closures, types of output. Sample runs are invited.

## ***1976 NSS CONVENTION ABSTRACTS (Morgantown, West Virginia)***

### **Electromagnetic Locating, an Accuracy Evaluation**

Charles S. Bishop and Frank S Reid

Horizontal positions and depths of underground points can be obtained using electromagnetic locating equipment. Accuracy of the results obtained has been mostly speculative in the past. During 1975, work was conducted to obtain quantitative values for the errors associated with positions and depths obtained using this equipment. Sixty Locations were made at Blue Springs Cave, Indiana, and Mammoth Cave, Kentucky, determining both horizontal position and depth. These results were then compared with similar results obtained from precise surveys. The surveys were to a precision exceeding 1:5000 but less than

1:10,000 for horizontal position. Elevation differences were based on leveling that exceeded third order accuracy requirements.

The accuracy of horizontal positions obtained is directly related to depth. At depths of less than 100 feet, errors in horizontal position of less than 0.5 feet resulted. At 200 feet in depth, the error in horizontal position averaged 7.0 feet. Depth determinations were consistently less than the actual value. At a depth of 74 feet, the determined depth was 97.6% of the actual value, and at 200 feet, 95% of the actual value was obtained.

Results of this project indicate that there are limitations to the capabilities of this type of equipment. The quantitative values for the errors are directly related to depth and the associated factors of signal strength, null width, and atmospheric noise. With the limiting factors known, it will be possible to better plan the use of electromagnetic locating equipment to obtain the most accurate results for controlling and checking cave surveys.

## ***1983 NSS CONVENTION ABSTRACTS (Elkins, West Virginia)***

### **An Application of Interactive Graphics to the Study of Caves**

Fred L. Wefer, John W. Igoe, and P. Ann Gillen

A 3-D interactive computer graphics program designed to aid in the study of the geomorphology of caves is presented. The program provides three basic types of operations: dynamic, function, and script. Dynamic operations include the ability to scale, rotate, and translate the 3-D map interactively. Digital readouts indicate the scales, viewing angles, and the map coordinates at the center of the view. Function operations include the ability to make visible or invisible various portions of the display (that is, fiducial marks, grids, topographic overlays, north arrows, etc.), to produce hard copies of the display, and to perform complete predefined dynamic oscillations in pitch, yaw, and roll. Script operations provide the ability to interactively define, edit, and run movies composed of sequences of dynamic and function operations using the technique of key-frame animation. Topics covered in the presentation include: the user interface, data

input methods, the graphics software and hardware employed, and video recording techniques. Examples of the program output feature the Butler Cave-Sinking Creek System in west-central Virginia. The presentation is made using color plotter output, color slides, and video tapes.

### **Results of the DC Grotto Compass Course**

Bob Thrun and Tom Kaye

Members of the DC Grotto set up a compass course to calibrate their instruments. This paper discusses results of analysis of over 1,600 compass observations made on the course. Data were analyzed for the entire population and for various subsets such as individual readers, individual compasses, types of instruments, etc. Implications of the results in actual cave surveys are discussed.

### **CAVPT: Cartography by Computer**

Don Conover

Adding the third Dimension to a cave map gives a more accurate representation of the relative height and depth of cave passages. This is particularly helpful in the study of the hydrology of a particular cave system. The maps also show the multiple levels of the passages relative to each other in the cave system. The program was originally written for an IBM 1130 and the results were plotted on a CALCOMP 718 flatbed plotter. The program has also been on an AMDAHL 470 and a CDC 6600. The plots have been output on CALCOMP pen plotters, VERSATEC electrostatic plotters, and TEKTRONICS CRT's (using PLOT 10 routines).

### **Advanced Computer Graphics Techniques**

Paul Hill

The use of state-of-the-art graphics hardware and software allows some very interesting cave maps to be generated. A number of computer generated cave maps will be displayed and the techniques for their generation discussed.

## **An Integrated System for Processing Cave Survey Data**

Douglas P. Dotson

Recent trends in small computer systems technology has brought reasonable computing power at low cost to many cavers. Other than the clerical applications of these computers, the most popular use of computers in caving is survey data analysis. Most existing software operates by placing the raw survey data in a file using text editor or word processor, and then using the file as input to a BASIC or FORTRAN program. The following paper describes an integrated system which supports all phases of cave survey data analysis. Although not entirely implemented, the described system handles data entry, analysis, loop closing, plotting and survey file maintenance.

## **1984 NSS CONVENTION ABSTRACTS (Sheridan, Wyoming)**

### **Algorithms for Getting Out of a Cave**

Richard L. Breisch

Five different algorithms for finding one's way out of a maze (or a cave) have been published in the literature of the mathematical specialty of graph theory. Three more methods have been devised by the author. Each algorithm is a set of simple rules which allow a person, who has no knowledge of the organization of the cave passages, to eventually find his way to an entrance.

Which algorithm is the most efficient? How can one compare the relative efficiency of a set of algorithms? Is one particular algorithm more (or less) efficient than the others?

The work to date has centered on defining precise measures of efficiency and using these to compare the algorithms. These procedures have been applied to caves small enough so that the measures of efficiency can be calculated exactly by hand.

It may be too hard to obtain an exact evaluation of the measures of efficiency when the algorithms are applied to large maze caves, so the next step of this investigation is to evaluate the measures on a computer using the Monte Carlo method. To do this, the cave is first described in the computer.

Each algorithm is implemented with a subroutine. A random number generator is used to select the passage for the lost person to try. The rules of the algorithm under test are applied, and the distance traversed from the start to an entrance is tabulated. This is repeated a large number of times, say 1,000 to 10,000, for each algorithm. Estimates of the measures of efficiency can be calculated from these repeated trials

### **Database Management for Cave Inventory**

Dave Derowitsch

A database management system has been developed that is capable of storing and retrieving pertinent information on caves. Data can be stored as unencoded unique entries or as encoded categories. Fast, efficient multiple field searches are implemented through the use of modified binary search trees on the unencoded fields and linked lists on the encoded fields. The system is easily adapted to a wide range of hardware since all hardware specific code is contained in a few small routines that perform the logical to physical translation. The supporting configuration and utilities programs allow the user to easily design, install, and subsequently modify a specific database.

### **A Final Report on the SMAPS Cave Survey System**

Doug Dotson

At the 1983 Convention I presented a talk describing the initial efforts in the development of an integrated system for the reduction of cave survey data for microcomputers. This project, the Survey Manipulation, Analysis, and Plotting System (SMAPS), is now complete. This final report will discuss the features of SMAPS, the design philosophy chosen, and the problems encountered during the development of the system.

### **An Analysis of Survey Compass Errors**

Tom Kaye and Bob Hoke

At the 1983 NSS Convention Tom Kaye and Bob Thrun presented preliminary results of a study of over 1,600 observations with various types of survey compasses under controlled conditions. This paper extends the analysis and compares the expected

accuracy of the different types of instruments. The human factor in surveying is also analyzed by comparing the instrument reading accuracy of different personnel under the same test conditions.

### **Cave Modeling**

Kirsten Stork

Surface modeling has been receiving increased attention within the computer community in the last few years. This led to the project of creating a cave modeling system, the first stage of which is presented here.

In this system, the user is provided with a three-dimensional representation of the survey data as well as an interpretation of these data with walls instead of the simple survey skeleton. It is assumed that the data include measurements from a survey point to the left and right wall as well as to the ceiling and floor.

In addition, an editor is incorporated to allow interactively changing the cave walls. Initially, the editing features have been limited to adding, moving, and deleting wall points.

### **The Surveyors vs. the Software**

Paul A. Hill

Today many surveyors are using computers to reduce cave survey data. The computer user is presented with the problem, on the one hand, of duplicating the data in the computer in a form similar to what was originally recorded and, on the other hand, formatting the data for use by the cave survey software.

Because of the diversity of caves, the cavers, and the uses of the data, it seems an unwise and an impossible task to attempt to standardize cave survey data formats. Given this situation, what is needed is a translator that can understand a wide range of cave survey formats and convert the data to a form understood by different cave survey programs.

A parser specifically designed to convert a multitude of data formats, as entered directly from survey notes, to a multitude of alternate formats for later processing has been constructed. The syntactic properties of cave data including many real examples will be discussed to show that the

possibilities, while varied, fall within limits that are predictable and reasonable.

The functions of the translator that was built will be presented to show how data in a mostly original form can be combined with commands to the translator in a way that is both readable by the average cave surveyor and understandable by a reasonable size computer program.

### **An Analysis of Instrument Reading Errors in Cave Surveys**

Bob Hoke

Analysis of data gathered at a survey contest held at the 1983 (West Virginia) Old Timer's Reunion revealed an unexpected number of blunders by experienced cave surveyors. Although the contest was held under near optimal conditions, the 39 contestants made over 25 significant errors in reading their instruments. This paper describes these blunders and makes a strong argument for using backsights to detect blunders before leaving the cave. An analysis of the inclination errors (all of which were on Suunto instruments) indicates that a modification to the scale markings (by the manufacturer) might make the instrument less prone to reading errors.

### **An Overview of Cave Survey Project Data Management Techniques**

George Dasher

This short paper will provide a brief synopsis of the different survey data management techniques incorporated in mapping caves of short, intermediate, and long length. The discussion will center on computer and non-computer compiling and storage of the coordinate data, as well as the closing of major loops within a cave system, survey quality control, personal attitudes toward cave mapping, personnel management, and potential and prevalent problems encountered by cave surveyors. Survey programs for both in-house computers and hand-held programmable calculators will be available for inspection. In addition, slides will be shown and there will be ample opportunities for interested persons to ask questions.

## **Xanadu: Survey and Cartography Considerations of a Multi-Level, Multi-Mile Cave System**

Charles Clark

Xanadu Cave runs for better than 23 miles beneath the slopes of the Obey River gorge in Fentress County, Tennessee. Yet, this entire system is contained underneath an escarpment with a total linear extent of just over one mile. Xanadu's entire expanse is contained within two-tenths of a square mile. Obviously, such a dense concentration of cave passage on multi-levels creates serious obstacles to the cave mapper in: 1) organizing his survey and 2) drafting his cave map.

Xanadu has been organized for exploration and survey purposes into three major sections (Xanadu, Zoroaster, and Alph) and six subsections. Each section is surveyed and plotted by a master surveyor, and each section is plotted on separate section maps as well as the comprehensive Xanadu map.

The survey and map project has fallen upon the shoulders of two chief surveyors, project head Jeff Sims, and Charles Clark. Each surveyor has separate in-cave and cartography responsibilities. As the survey nears completion the question of how to produce the final map arises. Jeff Sims advocates publication of the comprehensive Xanadu map, while Charles Clark advocates publication of a portfolio of section maps. Questions of map use, sublimity, or practicality will one day determine which map will prevail.

## **Projection Techniques and Map Construction**

Stephen Attaway

Correlating the entrance locations and principal passage orientations of different caves with their topographic and geographic environment is an important contribution to understanding the geomorphology of caves. One method of achieving these correlations is to produce maps that depict surface topography, cave entrance locations, and horizontal projections of major cave passages. The maps may be examined to visually interpret trends among these parameters. The author has developed a Fortran computer program that will use a large, high-resolution vector plotter to generate overlay maps that depict cave entrance locations and their

associated map. The overlay maps are constructed using the same projection techniques used by the U.S. Geological Survey (USGS) to make standard 7'30" polyconic topographic maps and the larger 1:1,000,000 metric Universal Transverse Mercator topographic maps. One may accurately superimpose the overlay maps on standard USGS topographic maps. In addition, programs were developed to produce large-scale maps of cave entrance locations based on projection techniques that do not yield area distortions. This paper presents the fundamental ideas and the equations needed to formulate these types of computer programs for cave entrance locations based on latitude and longitude. Large scale maps of Tennessee, Alabama, and Georgia are used to present the distribution of caves with documented locations in those states.

## ***1985 NSS CONVENTION ABSTRACTS (Frankfort, Kentucky)***

### **A Fortran Survey Program with Plotting Routine**

Roger V. Bartholomew

A Fortran cave-survey program is described which incorporates plotting routine which gives a rough plot of the last digit of each survey station in its approximate position on one page of the output. The program alternates on page of input data with one page of computations which include not only x, y and z coordinates, but also, the horizontal polar vector with an angle that can be used for plotting with a protractor and ruler. A coding system allows a survey over a level body of water in the cave to be done without using vertical angle measurements. The program also prints the z coordinate in meters. Another feature allows the correction of individual sightings for changes in the magnetic declination when the survey extends over several years.

### **Cave Cartography by Computer**

Don Conover

Adding the third dimension to a cave map gives a more accurate representation of the relative height and depth of cave passages. This is particularly helpful in the study of the hydrology of a particular cave system. The maps also show the multiple levels

of the passages relative to each other in the cave system. The computer program draws the passage walls and ceiling in the shape of the cross-section of the passage.

### **The SMAPS Program**

Doug Dotson

The SMAPS system is an interactive integrated system which supports all phases of cave survey data reduction. It has been implemented to allow portability to a wide variety of computer systems from mid-sized microcomputers to large mainframes. Since its introduction at the 1983 NSS convention, SMAPS has received much attention throughout the caving community and many suggestions have been made regarding improvements. As a result of this feedback, major design changes have been implemented. This presentation will discuss both the successful and unsuccessful improvements to the SMAPS system as well as the techniques used in their implementation.

### **PGD – Printer Graphic Driver**

Robert Thrun

Drawing lines on paper is an essential part of cave survey data reduction. The lack of suitable commercial software for doing this was the motivation for writing the Printer Graphics Driver. It reads a file with coordinates of line endings and produces line plots on the printer. The textbook algorithms fail to consider the real world limitations of microcomputer systems. PGD produces large plots, at high resolution, with full printer speed, using limited memory. This paper describes the design considerations that went into the program.

### **A Partitioned Semantic Net Design for Field Computer Applications**

Duane Vore

A pad of paper and a pencil are a more practical in-cave data system than a computer unless the computer's programming is able to assist the caver by making inferences of the data and drawing conclusions. Artificial intelligence technology can reach this goal, but current environments for its development like LISP, Smalltalk, and OP55

typically require hundreds to thousands of bytes per instance (node, frame, rule, etc.). This paper describes a knowledge representation scheme appropriate for a small portable computer.

Because of its hierarchical nature, cave knowledge, including implicit knowledge assumed by current survey data techniques and geological and biological knowledge, is easily represented by semantic net. By using a system of attribute chaining and adding the notion of frame slots, a conventional semantic net can be modified to optimize memory requirements. Arcs are implemented as a linked list of typed pointers, and nodes are data structures whose elements (slots) are defined by parallel nodes in another network partition.

Although the original intent of this design was to represent specific knowledge about a cave, it proved to be effective for other aspects of knowledge processing, allowing a common set of operators to be used. The final network is partitioned into specific knowledge, production rules and scripts, dynamic blackboards, metaknowledge and node descriptions.

## ***1986 NSS CONVENTION ABSTRACTS (Tularosa, New Mexico)***

### **A Look at Compass and Clinometer Error in the OTR Survey Course**

John Ganter

Data from the survey courses held at the 1983 and 1984 WV Old Timers Reunions was examined in an attempt to determine the types and sources of error present. Both populations of readings for specific instruments and shots and traverse misclosures were considered. Systematic error became visible when individual instruments were compared over populations of both shots and users. Random error is more elusive, but its magnitude appears to decrease with user experience, and increase with both shot inclination and shot length. Oddly enough, the relationship between a user's total deviations from the averages established by his fellows, and his resulting traverse misclosure, appears to be weak. Larger samples and better course design will be required to explain these relationships more clearly.



## **Laser Profiles of Cave Passages**

Bob Buecher

Several methods are described for using a small, battery powered, Helium-Neon LASER to determine ceiling heights, cross-sections and passage profiles in caves.

The methods discussed all involve using the LASER to project a small, bright point of light that is used as a target; normal cave surveying instruments are used to determine the position of the target.

The four methods that have been used to assess the usefulness of the LASER in cave surveying are: (1)

Right triangle ceiling height determination; (2) Simultaneous Triangulation with two instruments; (3) Intersecting the plane formed by rotating the LASER about a fixed axis; (4) Use of an Optical Rangefinder and LASER target.

## **Cave Mapping System, Version IV.4**

Steve Peerman

CMS allows a user to build files of cave survey data containing for each record, the name of the present and previous station, the distance, azimuth and elevation from the previous to the present station, the X, Y, and Z (E-W, N-S, and Vertical) coordinates of the present station, and finally the left wall, right wall, floor and ceiling distances from the present station.

Various routines allow the user to enter, modify, display, print out, or make maps from the data. In data entry, users may use feet and inches, feet, or meters; directions may be in azimuth or bearing form; backsight data may be included, and instrument and light height may be recorded and accounted for. Comments may be imbedded anywhere between records of data.

Data modification options allow conversion from feet to meters (or vice-versa), loop closure; data entry error correction, loop closure, data entry error correction, changes to azimuth values in entire files (for declination corrections, etc.). All files may be displayed on the screen printed out at the users option.

The user may display or print out stick maps based upon the files created. Plan views and profile views can be made. Plan views can be oriented in any

direction, drawn to any scale, and centered about any point. Profiles can be along any axis, drawn to any scale, and centered on any point. The user may include scale grids or station names on the maps if he wishes. The user may also display or print out rose charts showing distributions of shot directions.

## ***1987 NSS CONVENTION ABSTRACTS (Sault Ste Marie, Michigan)***

### **Working Drawings for Show Cave Development**

Russell H. Gurnee

Show cave development is the modification of a natural cave to provide a supervised, safe, and satisfying educational experience for the public. There are less than seven hundred caves open to the public in the world today. However, there are three times that many that were opened, modified, then closed. There are no schools or classes to aid the aspiring designer. In fact, most of the caves open to the public have been first-time efforts of the designer, architect, and workmen. Sort of like do-it-yourself brain surgery.

An operational program was used on three projects where the design was the result of the cooperation of individual specialists to achieve the best results. To show the relationship of the designer to the work crew plans and specifications are available for the following caves:

Harrison's Cave, Barbados, W.I.

Rio Camuy Empalme Cave, Hatillo, Puerto Rico

The Fountain, Anguilla, British West Indies

### **Controlling Survey Accuracy**

Ray Cole

In completing a large cave survey like the Caves of the Organ Caves Plateau the first question asked by a potential user of the caver produced surveys is about the relative accuracy of the passages and geological features. To help control the levels of error and estimate their magnitude requires a combination of accurate surface surveys, cave radio locations, and computer processing. A method was developed for estimating potential survey error

based on the string closure adjustments of the highly constrained survey data.

### **Ohio Cave Survey**

H. H. Hobbs III

For the past eight years the Ohio Cave Survey (OCS) has been an active organization. Physiochemical and biological sampling have been important aspects of the OCS as well as surveying. The caves of the state have never been documented other than lists made by a few individuals, thus much above ground as well as subterranean field work has been and continues to be a necessary part of the OCS. At present, 107 caves have been mapped or are in various stages of completion. Many of the maps have been published in the Wittenburg University Speleological Society journal, "Pholeos."

### **Large Cave Survey Management**

Jim Borden

The Central Kentucky Karst Coalition (CKKC) has been surveying the caves of Toohey Ridge since 1974. The most notable of the caves has been Roppel Cave which was connected to Mammoth Cave in 1983, creating a cave in excess of three hundred miles of passages. The CKKC has surveyed over sixty miles of cave in over 13,000 survey points.

The CKKC has fielded over 375 underground and surface surveys in four different caves. A logging system has been developed which catalogs notes, tracks ties between surveys, differentiates between multiple uses of survey letter designations, and provides accounting and organizational capabilities. All surveys are in one database, notes and trip reports are available to explorers and cartographers, and most survey errors have been detected and corrected.

Considering the tens of thousands of volunteer hours, expense, and sacrifice by a strong corps of volunteers, we try to insure the integrity of our efforts.

### **A Computer Applications System for the Processing of Cave Survey Data**

Daniel A. Crowl

An advanced computer-based cave survey processing system is described. This system supports the following features:

1. flexible raw data processing supporting a wide variety of survey instrument configurations.
2. user friendly output with full commenting.
3. loop closure.
4. full database generation and manipulation. This significantly reduces processing time and provides enormous flexibility for later graphics processing.
5. an interface to a computer aided graphics system enabling production of high quality map sections in a short period of time.
6. quick turn-around of new survey data.

The system is currently being used to support the Fisher Ridge, Roppel, and Crumps cave survey projects. This represents over 25,000 survey stations and 100 miles of cave.

### ***1988 NSS CONVENTION ABSTRACTS (Hot Springs, South Dakota)***

#### **Karst Research and Knowledge: Do We Need Karst Information Systems?**

John Ganter

Karst study, both as theoretical and applied research, and in the service of engineering, considers problems which are fundamentally spatial. Examination of three explanatory studies (at regional, karst basin and cave passage scales) reveals that information is dealt with at several logical and measurement levels, covers a remarkable size range, and is stored in a variety of formats. Hypothesis generation, induction, and analogous reasoning all seem to involve cognitive processing (setting up, refining and correcting a "mental model"), tacit thought (problem-solving drawing on short and long-term memory), and the generation of explicit knowledge in both propositional (text) and image form. A cycle ensues in which the geologist interacts with both this "created knowledge" and the phenomenon, testing and refining each against the other. The possibility of using digital means to provide increased interaction between geologist and

information is examined, and some design criteria are proposed.

### **Statistical Aspects of Cave Surveying**

Langford Brod

Station line lengths were compiled from the survey notes of several large caves in Arizona and Missouri, and the lengths were tabulated in one-foot increments. Cumulative distributions of number versus length were plotted to obtain the means, and histograms were prepared. The length plots were unimodal but not Gaussian, with the means dependent upon cave geometry. Curve fitting showed that the distributions most closely fit the equation  $N = KL \exp(L)$  where L is proportional to station line length. For small angular errors, the displacement error was considered to be perpendicular to the station line and proportional to the product of compass angle error and station line length. Total displacement error and the summation of the individual displacement errors, were generated using Monte Carlo methods in a computer program. The total displacement error was a function of assigned error parameters.

### **Micro-Based CAD for Cave Map Drafting**

Miles Hecker

In the 1986 Convention at Tularosa the author presented the results of the first large scale full cave map attempted on computer. The map of three mile long Fossil Mt. Ice Cave presented at that time was done almost totally on a VAX minicomputer costing \$100,000. Since that time, the techniques used have been successfully transferred to work on an IBM PC or PC/AT microcomputer costing less than \$1,500. The software techniques and hardware used to produce the new map of six mile long Horsethief Cave on such a system will be discussed.

### **Use of LORAN-C Equipment for Karst Inventory Projects**

Robert Hoke

LORAN-C is a radio navigation system that allows ships to determine their absolute latitude and longitude easily. Relatively cheap (\$650) portable units have recently become available and one is being used to pinpoint caves and karst features in

Pendleton County, West Virginia. Despite the area's rugged terrain the unit is normally able to determine locations within 200-300 feet when proper operating procedures are followed. Accurate location of a karst feature depends on numerous factors, including area of the country, LORAN signal strength, proximity to a known geographic location, weather, and terrain. Standard procedure normally involves calibrating the LORAN unit at a nearby road intersection that can be accurately located on a topo map, then walking to nearby karst features. The LORAN unit constantly displays the correct latitude/longitude as the user walks to each feature. This unit is being used in gathering location data for a planned publication documenting the caves of Pendleton County.

### **An Evaluation of the Autohelm Personal Compass for Cave Surveying**

Roger V. Bartholomew

A battery operated electronic fluxgate compass with a digital liquid crystal display readout developed by Nautech, Ltd. in England has recently become available in the U.S. The compass is used for sailing navigation and is water-proof. Specifications: fluxgate compass  $\pm 1^\circ$ , basic accuracy  $\pm 2^\circ$ , repeatability over three bearings within  $3^\circ$ . No compass needle means no settling time and no delay: just point and press a button. A ten minute memory stores up to nine bearings, as fast as you can click the record button. It has a stopwatch: 0 to 10 hours count up or a ten minute to zero countdown. The compass looks like a stretched Suunto (6"x2.25") and has gunsight devices along both top edges. Although the accuracy is rather poor, its speed and elimination of Suunto scale fogging problems may make it useful in difficult cave surveying situations. Results of closed loop traverses will be presented.

### **Display of Survey Closure Errors**

Robert Thrun

With the routine computer processing of cave survey data, we are able to evaluate survey closure errors. The closure errors are approximately the lower bound on the random errors in the survey. The problem is how to evaluate the closure errors to see how these errors compare between surveys. A simple one-number average is not satisfactory.

Different parts of the survey have different errors. Various quantities may be plotted on a graph: absolute adjustment (error), percentage adjustment, comparison with assumed error, length of adjusted string, number of shots in string. These may be plotted with linear, log, or cumulative scales. The purpose of this paper is to show how the computer output may be displayed so that we can evaluate the survey errors. Only then may we begin evaluating the surveys.

### **Planetable, Theodolite or Compass? Search for Accuracy in Survey of a Lava Tube Research Preserve in Hawaii**

Fred D. Stone

As a condition for establishing a proposed cave research center and preserve on the island of Hawaii, the state Land Management Division required an accurate survey of a lava tube. Due to closure errors, we surveyed the tube 3 ways using the same stations; with planetable and alidade, with theodolite, and with two tripod mounted compasses. We used Lotus 1-2-3 to analyze and compare survey data and to produce the cave maps with land boundaries superimposed.

Survey accuracy was determined from a 650m transect between two entrances with a 658m surface closure, and by comparison of the 3 surveys. Closure errors for the 3 surveys were: alidade, 12m; theodolite, 18.7m; compasses, .4m. Although theodolite sightings were the most accurate (2 per station, average difference 4.5' std 4.8'), and compass the least (avg. diff. 21' std 1°44'), total closure gave opposite results. The reason is that both theodolite and alidade sightings are turned from previous sightings, so errors are cumulative, while compass sightings are independent, and errors cancel. Effects of paleomagnetism and iron minerals on compass readings were apparently not critical. Use of the planetable allowed detailed mapping of cave features, and future work will combine 2 tripod mounted compasses with planetable mapping.

## **1989 NSS CONVENTION ABSTRACTS (Sewanee, Tennessee)**

### **Rivalry Error in Two-eyed Suunto Sightings**

Roger V. Bartholomew

If two eyes are used to sight the Suunto compass as the manufacturer recommends, "so that the hairline [seen by one eye] is superimposed on the target" [seen by the other eye] there will always be what I shall call a rivalry error in the azimuth.

In any two-eyed Suunto sighting, the system is forced to superimpose images of hairline and target station, each located at different distances from the eye. This causes a rivalry over which eye will control the convergence angle of the optic axes of the eyes. This misuse of the human binocular vision system causes rivalry error. Heterophoria, a biological condition, can add another error which may increase or decrease rivalry error but heterophoria is not the cause of rivalry error.

Experiments show that rivalry error is normally greater than  $1/2^\circ$ .

### **Useful Techniques from Survey and Cartography Standards for the Romanian Speleological Institute**

Robert Cronk

Several techniques for cave survey and cartography were learned from the recent NSS expedition, ROMANIA 88, a joint Romanian-American expedition to investigate some recently discovered caves in the Biho Mountains of Transylvania. The expedition was sponsored by the Emil Racovitza Institute of Speleology in Bucharest, Romania and supported by the National Speleological Society through an International Speleological Partnership grant.

Romania contains several major karstic areas. Over 10,000 caves have been catalogued. The region of the Bihor Mountains in Transylvania is only now coming under intense exploration and several major discoveries have been made. The expedition team investigated many caves during July 1988, the most important of which was Piatra Altarului, a large, highly decorated cave discovered less than a year earlier.

The map of Piatra Altarului is used to illustrate several interesting techniques which could be applied to large-scale survey and cartography efforts: (1) passage contour lines, (2) standards for total passage length measurements for caves with large rooms, (3) markings on plan views for passages intersecting at different levels, and (4) independent inspection/verification of accuracy.

## **1990 NSS CONVENTION ABSTRACTS (Yreka, California)**

### **Tilt Error in High Inclination Suunto Compass Sightings with the Glass Rod Cylindrical Lens**

Roger V. Bartholomew

For Suunto compass sightings with large inclination angles a glass rod mounted slightly beyond the Suunto case decreases the angular separation of the Suunto cursor line and the target light and allows easy alignment of the Suunto cursor and the light beam emerging from the glass rod. Lang Brod has cautioned that the compass must be perfectly level to obtain a true compass reading.

A preliminary experiment on an azimuth of 242.0 degrees with a +44.2 degree inclination angle has shown that 1.0 degree of tilt causes a 0.85 degree error in the azimuth reading. In the same experiment, an attempt was made to level the Suunto according to Brod's suggestion: "so that the upper and lower edges of the drum dial are nominally parallel to the upper and lower edges of the rectangular inner window observed through the lens". The result was an error of 1.4 degrees in azimuth and the tilt measured 2.2 degrees.

These results suggest that for greater precision another method of leveling the compass is needed which is independent of the orientation of the Suunto compass drum. The compass drum orientation is affected by compass dip which will cause different errors at different azimuth angles.

### **An Evaluation of the Smartlevel as a Survey Inclinometer**

Roger V. Bartholomew

The Smartlevel is a digital inclinometer developed for use as a carpenter's level. It measures inclination angles from +90 to -90 degrees to the nearest 0.1 degree or precision can be selected to the nearest 0.2 or 0.5 degree. Other modes include rise over run, percent of slope, or simulated bubble. It has a rugged solid state sensor and a liquid crystal display, sealed inside a weather resistant (not weather proof) polycarbonate module. It requires a 9-volt battery. Recalibration is easily done by placing it on a slope, pressing a button, turning the level around and pressing the button again. The display flips over so you can still read it when it's upside down.

Disadvantages for cave survey include: LCD faces 90 degrees to the line of sight so that it must be tripod-mounted or a Brunton type mirror/pointer arrangement must be used. There is no sample and hold button so that it can be sighted and read at different times.

Mfg: Wedge Innovations, 532 Mercury Drive, Sunnyvale, CA 94086, Cost \$89.95 + \$6.50 posting & handling.

### **Standards and Criteria of the NSS Cartographic Salon**

George Veni

During the 1989 NSS Cartographic Salon, a new judging method was tried and was favorably received. As a result, a committee formed to fine-tune this new methodology and has since published the results in *Compass and Tape*. The committee's goals were to develop fair standards which would be consistent year to year, and which would serve as a model for cave cartographers on what constitutes a "good" map. Committee members came from various parts of the country to prevent setting standards which represented a particular region's style or biases. An overview of the new methodology and standards shall be presented. Discussion will be encouraged.

## **Mapping Non-limestone Caves**

Carol Vesely

In California there are many different kinds of non-limestone caves: lava tubes, granite "purgatory caves", "mud caves" and sea caves, each of which present their own challenges to the map-maker trying to survey and represent them. Moreover, the techniques used to portray these "unusual" caves are applicable to limestone caves as well. In surveying sea caves and mud caves, cartographers have been forced to develop new symbols and to wrestle with the difficult questions of "is a cave?" and "where does it begin?". In granite caves, we encounter the problem of portraying complex routes through breakdown. In pseudokarst areas one of the most significant aspects of the individual caves is how they related to the surrounding geology and to each other. Extensive use of small area maps have helped give the maps of these small caves more meaning.

## **The Survey of Underwater Caves**

Ron Simmons

This will be a general overview of how underwater caves are surveyed. The techniques are different from the survey of air-filled caves due to the need to take a life line support system along and the limited time available to accomplish the goal. There is also a difference in the quality and accuracy of the finished map depending on the diving conditions. The survey of sumps tend to be only a line plot while the survey of underwater caves in Florida or the Yucatan can approach the best surveys of air-filled caves.

## **Cartography at Lilburn Cave**

Peter Bosted

Lilburn Cave, located in Kings Canyon National Park, California, is an 11+ mile long three-dimensional maze cave formed in banded marble. The passage complexity presents special cartographic challenges which are being met using a variety of computer-generated and hand-drawn maps. The computer maps use either gray tones or color to portray the various passage levels (plan view) or distance from the viewer (profile). Passage shapes are calculated from a smoothing algorithm. Hand-drawn maps which show passage detail are

being produced for both the entire cave and, in quadrangle format, for each level in a given area.

## **Lechuguilla Cave - a Cartographer's Nightmare!**

Patricia Kambesis

The complexity of Lechuguilla Cave has presented the project's Cartography Committee with the challenge of portraying this cave on paper. On a grand scale, Lechuguilla Cave can be divided into four distinct regions: the Upper Cave and Rift, the Western Borehole, the Southwestern Borehole, and the Eastern Branch. Within each of the major sections, the morphology and interrelationships of the passages take on the character of a series of intricate three-dimensional mazes (boneyard).

The great lateral extent of Lechuguilla has made it necessary to partition the cave into quadrangles (1000 feet long by 1500 feet wide) that tie into the same quadrangle system used at Carlsbad Cavern. Line plots are superimposed on the quad grid and each quad is plotted out separately. Because some of the quadrangles consist of cave passage on at least four different levels, it has become necessary to generate "isopach plots" i.e. distinct layers of cave passage with upper and lower boundaries defined by depth from the entrance. These depth defined isopachs can be layered on top of each other to show the relationships within the various areas of the mazes. Currently the quads are used as work maps to guide exploration, to define trade routes and as pieces of the beginnings of an interactive database. There are still many problems inherent in depicting Lechuguilla Cave. These include: use of cross sections, the most effective vertical profile, continuous influx of new data, and producing a "publishable" map.

## **Cave Visualization using Voxels**

Richard L Breisch

"Voxel" stands for "volume element". It is a method of storing image data about 3-dimensional objects in a computer database. The objects are represented by a 3-dimensional array of small cubes. Each voxel has user-defined attributes such as 3 coordinates, color, material type, translucency, or any other factor which has been specified by the creator of the database. By using voxels, it is now theoretically

possible to create cave scenes which can be manipulated in realtime by the viewer as if he were walking through the cave. Cave mapping, stereo-photography, and fractal computations are required to create the voxel database. Using voxels to create realistic cave scenes would be very expensive, but it is an alternative to commercializing a fragile cave.

### **Cave Mapping for the Future**

Peter Sprouse

While there have been significant improvements in cave mapmaking in recent years, it seems likely that major changes are still to come in the realm of automated data processing and presentation. It is also likely that in using the advanced tools available to them, future cave mapmakers will find many deficiencies with our present-day surveys. Speculation on future mapping technologies can suggest ways to improve our current surveying quality, so that our surveys will retain a high yield over a longer period.

As we progress past computer-plotted survey baselines to plotting walls and floor detail, we can look ahead to detailed, accurate cave modeling in true 3-D. Stereo computer monitors, holographic projections, and programmable three-dimensional media are all possible ways that we may someday create miniature replicas of the caves we survey. Accurate surveys and detailed sketches will of course be needed, but most urgent will be the need for more 3-D data in the form of complete profile sketches and prolific cross-sections. While someday advanced instruments may make all necessary measurements for 3-D modeling, we can still contribute to better maps tomorrow by better using our sketchbooks today.

## ***1991 NSS CONVENTION ABSTRACTS (Cobleskill, New York)***

### **Use of a Laser Pointer for Accurate Surveys**

Hubert Crowell

One large source of survey errors comes from the vertical angles taken during cave surveys. The use of a laser pointer can reduce this error as well as improve the accuracy of compass sightings. Plans

for a clinometer and compass mount for use with a laser pointer will be presented.

By using two small tripods and a laser pointer, a beam can be projected from the forward station to align a compass and clinometer located on the rear station tripod. The laser pointer can also be used to locate points on the walls and roof and the angles to these points used to calculate the dimensions of large passages. The possibility of solo surveys without a tape measure is also raised using an offset mirror on the forward station and reflecting the beam between the two stations.

### **Locating Cave Map Sides with Minimum Survey Data**

Hubert Crowell

Drawing cave maps from minimum survey data can be a challenge for mappers or a computer program. Simple curving passages can be drawn easily from a survey line and side measurements. However when passages turn sharply or branch out and the mapper has only the left and right measurements to the sides, the map is open for wild guesses.

A procedure for locating the map sides will be offered when only the survey line and side measurements are known. Logical assumptions are made about extending the sides around sharp corners and locating inside corners for sharp turns and side passages. Connecting side passages can present a problem in locating the corners. This may not appear to be a problem for someone familiar with drawing cave maps, but what about a computer program that cannot make judgments?

### **CGIS - A Cave Oriented Geographic Information System**

Douglas P. Dotson

As more data is gathered about caves and their resources, it is becoming increasingly difficult to represent and manipulate this data to produce information. Geographic Information Systems have made vast progress towards solving these problems for above ground resources but fall short when applied to the unique problems related to caves and their resources. For the past year, a specialized Geographic Information System has been under development in cooperation with the National Park Service at Mammoth Cave National Park. This

presentation will discuss the features and applications of the developed GIS and the applications for which the system is useful.

### **Determining Cave Length and Quality - A Discussion**

Thom Engel

How is cave length best defined? Is Total Horizontal Length (THL) the most appropriate method or is it merely an artifact of how we draft maps? Is a method that more closely measures the distance a caver travels through a cave the best method? If so, just what would that method be?

Further, once an acceptable algorithm for defining cave length has been found and accepted can we say that it is the best way for describing a cave from a recreational perspective? Is some kind of objective cave quality index needed to tell the caver how much of a cave he or she will really see short of pushing every little lead? Is the idea of penetration (distance from entrance to furthest point in cave) an appropriate measure in describing cave quality and does it really provide useful information? Is there a better method or is the idea of measuring cave quality so subjective that no reproducible method can be developed?

### **Passage Walls Construction for Stage-4 Cave Maps**

Fred L. Wefer

A computer program called Interactive Cave Map (ICM) is being used by the author to explore the application of interactive computer graphics to the generation and display of State-4 cave maps, i.e., cave maps designed to be viewed on the computer graphics screen. ICM displays four basic types of information: traverse lines information, passage walls information, symbols information, and auxiliary information.

This paper concentrates on passage walls information. Previous attempts at showing passage walls on 3D computer generated maps are first reviewed. Some requirements for the effective display of passage walls information are then presented. A set of design elements which satisfy the requirements is next developed. Finally, the ICM implementation of these design elements is discussed, including the techniques used to input,

store, generate, and display both cross sections and passage walls.

Key to the success of the ICM implementation is the use of only information normally available from traditional cave surveys, i.e., no special surveying instruments or techniques are necessary. Hardcopies of the State-4 cave maps of Corkscrew Cave (an artificial cave used for testing the computer program) and also of Cueva Catanamatias (a real cave in the Dominican Republic) are used to illustrate the techniques.

## ***1992 NSS CONVENTION ABSTRACTS (Salem, Indiana)***

### **Progress with Cave Map Language; Survey Processing, Management, and Archiving of the Mammoth Cave Data**

Mel Park

The raw survey data for the Mammoth Cave System is contained in slightly more than 3,000 field survey books and that number is increasing by 15 to 30 every month. With that amount of data, the transcription to machine-readable form had better be a one-time process; the task of retyping all of that information into some new computer format is simply too staggering. In addition, the day-to-day management of so complex a data set is, itself, a formidable task. Therefore, the computer programs that handle our data must meet needs not previously thought necessary for cave survey programs. We set out to develop a system suitable for data archiving and-data management as well as performing the conventional processing expected of cave survey programs. The result, Cave Map Language, will be both explained and demonstrated.

Cave Map Language (CML) is a way of writing down all of the data that are collected by survey parties and doing it in a manner that is both easily read and maintained by humans and that can be read and processed by machines. As a format for data exchange, it is intended to be a tool by which underground survey data can be archived and transmitted. As a running system of computer programs that parse and otherwise manipulate CML data, it is intended to be a tool for the daily maintenance of survey data, the making of maps,



and the extraction of sets of data that can be sent to other computer applications and uses.

An abiding principal has been to make the language, and computer, conform to the way that data has been collected rather than making data transcription conform to some perceived requirements of the computer. Thus, every survey and data convention that has been used in the 35 years of work at Mammoth Cave is, or can be, provided for. Data using those conventions do not have to be converted to other units or coordinate systems before being processed by language tools. Survey data are written in plain text (ASCII) in close to the same way that they are written down in the raw survey notes. The data format is free, both in the ways that data are permitted to be arranged on each line and in the way that groups of survey data can be arranged. The language specification requires that the programs that support it allow forward referencing of data, that is, a station or survey do not have to be defined before it is referenced in another survey. There are provisions for embedding comments (textual data intended to be read by humans) and notes (textual data intended to be processed by machines) with the numerical survey data, just as one makes notes in a survey book.

CML is supported by a single large program and a growing number of smaller utilities for converting other data formats into CML. At its present state of development, the code is 12,000 lines of system-independent ANSI-C code. The program has been written to be platform independent and has been successfully compiled and used on Macintosh, MS/DOS, and IBM R6000 computers.

The program performs the conventional tasks of generating Cartesian coordinate data, doing loop closure, and generating graphics files. It serves as a data management tool in that it can produce a number of useful data summaries. For example, survey log sheets can be generated that show such things as the date, location, and personnel involved in a survey trip plus a schematic of the passages surveyed. CML interacts with SMAPS/GIS in ways that satisfy Park Service and CRF cartographic needs by producing Standard Exchange Format (SEF) files suitable for importing into SMAPS .

## **The Use of an Orienteering Compass for Sketching**

Dan Legnini

Application of a simple compass as a drafting aid for the sketcher will be demonstrated. An inexpensive, commonly available compass can be a great help when sketching to scale. Plotting of both plan and profile can be simplified with this one tool.

## **Formal Training for Cave Surveyors**

Angela Morgan and Tom Moss

The Fern Cave project was formed in 1991 with the goal of resurveying Fern Cave, Alabama. High standards for the survey were established. Because of the strict standards being followed and also because it was realized that many potential project members might not have the experience and/or skills necessary to perform sketching or perform instrument-reading functions on survey trips, training and certification procedures were established to train sketchers and instrument readers.

A two-day training course was developed for sketching and instrument reading. The first day of the course consists of a classroom session and a practice session; the sketching and instrument classes are separate on this day. On the second day, all the students are together and survey in a cave for several hours.

At the time of this writing the survey class has been taught twice. Discussion will cover details of how the course is taught, what has been learned in the process of teaching it, student reaction to the course, the project's certification procedures, and how the training and certification process has benefitted the Fern Cave Project.

## **SMAPS/GIS – A Cave-Oriented Geographic Information System**

Douglas P. Dotson

SMAPS/GIS was developed in cooperation with the National Park Service beginning in June 1990. The purpose of the project is to develop a Geographical Information System which was particularly suited to the unique aspects of cave resource management. The resulting system has been adopted as the

“standard” system for cave resource management in the NPS.

The presentation will begin by showing why traditional raster and vector based GIS packages fall short when dealing with cave related data. The remaining time will concentrate on the GIS related features available in the SMAPS Cave Management System and the SMAPS/GIS option. A hypothetical cave with many diverse resources will be used as an example of how data is managed and manipulated. A complete scenario will be presented which will show how the GIS may be used as a practical management tool.

### **Building the Database for a Cave-Oriented Geographic Information System**

Douglas P. Dotson

This paper will concentrate on the various methods for gathering data to build a database for a cave oriented Geographic Information System. A real world project will be used to illustrate, showing methods for gathering data from existing paper maps as well as gathering new data. The current cave inventory project at Wind Cave National Park will be used as an example of the inventory process.

Open Discussion – Is the Time Right to Propose a Data Exchange Standard Again?

At the 1983 NSS Convention in Elkins, West Virginia much discussion was devoted to the concept of establishing standards for the format of cave survey data. The discussion ended with the general consensus that a standard is probably not necessary since format conversion could be handled on an “as needed” basis, and that no one standard could satisfy all possible situations. Over the past two years a number of intense discussions have ensued primarily on the Internet Cavers’ Forum dealing with exchange standards. It may be time to re-address this issue.

The format of the discussion will be open. One or more short presentations of possible standards will be given with the intent of encouraging discussion. Anyone wishing to present their ideas will be welcome to do so. The discussion will be mediated by the session chair.

## ***1993 NSS CONVENTION ABSTRACTS (Pendleton, Oregon)***

### **GSS Pettyjohn Cave Project**

Hubert C. Crowell

The Pettyjohn Cave Project (PCP) was formed in an effort to compile as much information as possible on this great cave and make this information readily available to cavers. The format for the information is on 3 1/2 inch diskette with CAPSVIEW software for viewing on a PC with DOS 3.3 or higher and a hard drive.

All of the raw survey data is shown along with a 3-D map of the cave which can be rotated. A search method will be discussed for locating possible leads and points of interest within the cave. A demonstration will be given showing a tour through parts of the cave with cross sections, notes, and photographs.

The diskettes are distributed at cost plus 20% for the GSS. All cavers who have been involved with Pettyjohn’s Cave are encouraged to share the experience with others by sending us the information for inclusion on the disk. All trips will be placed in a file by date for others to read.

A well known cave like Pettyjohn’s points out a strong need to maintain detail records and maps. The efforts of many are lost due to not having a central location or collection point for cave data. A local Survey section can provide that collection point provided that the information is easily made available to others. I hope that future cavers will thank the Georgia Speleological Survey for maintaining the local cave records.

### **A Successful Management Cave Survey Project Case Study**

Bob Hoke

The 3-year effort to resurvey the 7+ miles of passage in Paxton’s Cave (Virginia) was an unusual project: it ran smoothly and efficiently, and the survey trips were consistently productive despite having over 90 different surveyors with varying skill levels. Some of the more significant reasons for the Project’s success were that survey quality was maintained by the consistent use of backsights, detailed sketches, and no booty scooping; data was

reduced and drafted quickly, with updated maps being available for every survey team on every trip; trips were open to all cavers and training was willingly provided to new surveyors; and various other organizational and personnel problems that frequently plague significant projects were avoided.

## **Designing a Generalizable Cave Inventory**

Carol Vesely

The Federal Cave Resources Protection Act mandates that cave resources on federal land be inventoried and management classifications be recommended for all caves. A variety of individual cave inventorying procedures have been implemented in specific parks and caves across the country. However, to date no nationally accepted cave inventorying system exist. I would like to foster a discussion of the pros and cons of various existing cave inventorying systems and solicit recommendations for a model cave inventorying system that would be generalizable to caves nationwide. Some of the topics to be discussed include: stages of cave inventorying, mapping standards, data base management, the role of scientific "experts" and inventorying forms and protocols.

## **Techniques for Using AutoCad for Cave Cartography**

Garry Petrie

During the past several years using computers to draw cave maps has become much more practical. Developments such as in-expensive, fast, high resolution displays, high capacity mass storage, 32 bit processors and programs optimize for the hardware have enabled individuals to create very portable and revisable drawings. One such computing platform and program is the IBM PC and compatibles using AutoCad.

While a program as complex as AutoCad has many methods to achieve similar results, all routes will include entering the survey data as a reference backbone, planning the layout of overlapping and connecting passages, rendering the walls, adding features, noting locations and references and eventual updating as new passages are discovered. AutoCad has many capabilities such as superimposing drawing layers, copying and changing

properties of symbols and lines, hidden line removal and z-plane sorting, trimming lines to a reference and area filling that are useful in drawing cave maps. One of the most important capability AutoCad has is the outputting of "electronic" maps at various scales for a variety of physical drawing devices.

## ***1994 NSS CONVENTION ABSTRACTS (Brackettsville, Texas)***

### **A 3D Symbol Set for Stage-4 Cave Maps**

Fred L. Wefer

A computer program called Interactive Cave Map (ICM) is being used by the author to explore the application of interactive computer graphics to the generation and display of Stage-4 cave maps, i.e., cave maps designed to be viewed on the

computer graphics screen. ICM display four basic types of information: Traverse Lines Information (TLI), Passage Walls Information (PWI), SYmbols Information (SYI), and AuXillary Information (AXI). This paper concentrates on SYI.

The symbol set, implemented using parametrized icons, allows the depiction in 3D of objects appropriately addressed by the "Basic Cave Map Symbols" of the 1976 NSS Standard, including: Passage Features, Speleothems, Floor Materials, and Miscellaneous. It should be noted that not all "symbols" in the 1976 NSS Standard address objects found in caves. Some are attempts to convey other types of information, e.g., cross sections and ceiling heights attempt to convey PWI, survey stations to convey TLI, and north arrows and scales to convey AXI. The icon parameters include three offsets from a survey station (for placing the symbol), three factors (for scaling the symbol), and three angles (for orienting the symbol).

Hardcopies of the maps of Corkscrew Cave (an artificial cave used for testing the computer program) and of Cueva Catanamatias (a real cave in the Dominican Republic) are used to illustrate the symbol set.

## **The OTR Compass Course**

George Dasher

In 1988, I took over the responsibilities of running the compass course at OTR. This course is an eight-station, seven-shot course, where contestants compete to see who can close a loop with the smallest error. Each year the layout of the course is changed, and there are often severe vertical shots incorporated into the design of the individual courses.

The end result of these five years is that I have managed to collect a good deal of data on the instruments most cavers use to survey in caves. Predominant among these instruments are Suuntos; Sistecos are a poor second and Bruntons a poorer third. I have tossed out all the "bad" data sets, averaged the azimuths and inclinations for each individual shot, compared the individual azimuths and inclinations to these averages, calculated a difference for each shot, and then averaged these differences. The end results are that I have found Suuntos to be the most accurate of the three instruments and that the clinometers are more accurate than the compasses.

And how much do most cave surveying instruments deviate from these averaged norths and horizontals? The compasses were typically 1 degree off the averaged north, and the clinometers 0.4 degrees off the averaged horizontal. The need for compass courses is obvious once a graph of all the data is viewed.

## **Application of Geographic Information Systems in the Study of Karst Groundwater Flow at the Drainage Basin Scale**

Kyle Bearden and Chris Groves

This research concerns the development of new tools and techniques for groundwater research and resource management in the Central Kentucky Karst. The flow patterns within karst drainage systems are closely related to original patterns of secondary porosity and are therefore site specific. In order to make informed management and planning decisions concerning these regions, detailed hydrogeologic investigations of specific drainage systems are required. The main focus of this project is to develop software tools that can be used to

store, analyze, and make available both spatial and attribute data that result from such investigations. Such data may include physical information on caves, dye traces, geology, and topography, as well as cultural information for the surface above a particular flow system, such as landuse and landowner data.

Geographic Information Systems (GIS) computer software may be applied to address this need. GIS programs are capable of storing and manipulating a variety of data types and are ideal for applications such as this which involve highly spatial information.

A GIS database structure was constructed for a "test" karst ground water drainage basin, the Poorhouse Spring drainage basin in northern Warren County. Data necessary for the accurate characterization of this flow system were identified, collected, and entered into the database. This system may be implemented to aid decision making in planning and resource management in the area and the methods used in development of the database can be utilized to develop GIS applications in other karst flow systems. An important focus has been to develop menus within the system to make the information accessible to individuals without extensive training in GIS.

## **Locating the Cave Entrance**

George Dasher

Recently, I have completed a publication on the caves of a drainage area in Greenbrier County, West Virginia. It has become painfully obvious that most cavers—including many experienced cavers—have no idea what to describe while locating caves in a given area or above the mega-monster-cave.

The proper method – which should prevent multiple trips to the cave to redescribe the entrance – should include not only marking the cave location precisely on a topographic map, accurately determining the coordinates, but also providing a good, written description of where the cave is located and of the appearance of the cave entrance. There is no such thing as too much of a written description.

The written description of the cave location should include items such as: Is the entrance north or south of a fence?, what trees or obvious rock outcrops are nearby?, and how far and what direction is the

entrance from the nearest road, valley bottom, or stream? Give azimuths to obvious locators –e.g., houses, barns, junk piles, etc., and include a sketch of where the cave is located.

The written description of the appearance of the cave entrance should include: The depth, diameter, and shape of the sinkhole, the diameter and shape of the cave entrance, is the cave entrance in bedrock or soil, are there any streams which flow into or out of the cave entrance, what is immediately above or below the cave entrance, and – if necessary – are there any interesting features in the cave entrance. This may include a picture of the cave entrance.

To summarize, it is very important to keep lavish written records of where each cave is located and of the appearance of the cave entrance. The bottom line is overkill, overkill, and overkill. The other option is 501 trips to the same cave entrance to re- and redescribe its location and appearance.

## ***1995 NSS CONVENTION ABSTRACTS (Blacksburg, Virginia)***

### **The Computerization of the Cave Map**

Fred L. Wefer

The computerization of many types of activities has tended to occur in identifiable and somewhat predictable stages that can be described nearly independently of the application. Stage-1 (simple)-portions of the activity which were previously performed without computers are “simply” computerized. Some portions are still done the old way. Stage-2 (enhanced) --the computerized version of the activity is “enhance to provide additional functionality. Capabilities are provided which were seldom done before because they were either too time consuming or too difficult. Stage-3 (complete) -the computerized version is further enhanced by the use of more sophisticated algorithms and added functionality, to the point where all or nearly all operations are performed on the computer. The computerized process completely replaces the previous manual process. Finally, Stage-4 (redefinition) --the functionality of the computerized version greatly exceeds that of the traditional activity. Aspects of the computerized version are recognized as new manifestations of existing ideas, processes, and/or products. The fundamental terms

previously used to describe the activity are redefined.

The activity of creating and viewing a cave map is undergoing such a “redefinition”. This review paper: discusses the four stages as they apply to the specific example of computerizing the cave map; gives example of the four stages; shows the time frame involved; defines some common terms used in discussing this subject; provides a general framework within which to understand computerized cave representations; discusses hardware and software implications and limitations; and provides an extensive bibliography for further reading.

### **Care and Calibration of the SONIN Combo PRO – an Electronic Distance Measuring Tool**

Hubert Crowell

With proper care and calibration the SONIN Combo PRO can be used in place of a tape for cave surveying. The unit in a cave environment can be used in the single unit mode to measure a flat surface such as a ceiling up to 60 feet and in the dual unit mode up to 200 feet.

Discussion will be on how to clean the contacts when the display fades and how to calibrate both the single unit mode and the dual unit mode. Other useful features are the ability to keep a running total of the survey length and the temperature at each station.

In the dual unit Node the SONIN Combe POLO uses a target. The target is activated with an infrared light signal and then sends sound waves back. This enables the distance to be measured through small or narrow openings.

### **CAPS User Group Meeting – New Features and Uses for CAPS**

Hubert Crowell

A brief overview of the new features of CAPS and some ways CAPS can be used to display information about a cave. CAPS is an available software program that converts raw survey data to a 3-D screen plot with sides, notes and the ability to display pictures at each station. Some of the new features that will be discussed will be the 3-D with glasses in order to

relate to the depth of the cave. A new search feature that shows where the requested information was found by placing small circles at each station were a match occurred. Using any ASCII text editor to expand the notes for each station and how the editor can be used from within CAPS to edit the notes. The ability to view your raw survey data in a table and edit the data.

### **Standards for Sketching**

Dale L. Pate

The key component of any cave survey is the information that is produced. On most cave surveys that information is in the form of a sketch or series of sketches and the notes. If when a team returns to the surface and the information brought out of a cave is not readable, hard to understand, or lacking in usable data, then the time spent by the team has been wasted and more importantly, the cave has been impacted without producing any viable results. In the caves of Carlsbad Caverns National Park, this impact to the caves with poor or no usable results is unacceptable. The caves of the park are very fragile and each team entering an area will have an impact. Therefore, it is imperative that good information be gathered. The sketcher is the most important member of the survey team. Standards have been developed to give sketchers knowledge of what is expected when they return from a survey trip. These standards will be discussed and examples will be given of bad as well as good survey sketches and notes.

### **Fundamentals of Computer-Aided Drafting Applied To Cave Cartography**

Bert Ashbrook

Computer-Aided Drafting (CAD) can produce finished cave maps at any scale. Three-dimensional screen projections enable visualization of vertical caves but are cumbersome to use. CAD maps on paper are more practical for horizontal caves.

Traverse lines may be imported into CAD programs or data reduction may be incorporated into the software. Scanning sketches directly into CAD programs is difficult. Walls are more feasibly transcribed as lines and “smoothed” mathematically, or deduced from “left / light / up / down” data. Detail may be custom-drawn or inserted from

libraries of standard symbols. Special hatches and line patterns are useful. The scale of the final presentation affects detail insertion.

In CAD, related data are sorted into “layers.” Layers may be displayed or hidden at will, producing different maps for different purposes. For example, maps for mop-up surveyors might display survey station layers which would be hidden in publication maps.

Experienced hand- and CAD-drafters draw with equal speed, but CAD is significantly faster when changes are necessary, especially for large caves. “Working” maps are eliminated. New data may be added indefinitely and maps produced at any time, so inked maps no longer signify project milestones. However, closing loops is problematic for some software.

CAD permits neat lettering using many fonts. Map elements may be moved easily to achieve balanced layouts. Although CAD enables sloppy drafters to do neat work, CAD does not replace the artistic talent and attention to detail required of great cartographers.

### **Forum on the judging of Electronic Maps for the NSS Cartographic Salon**

Patricia N. Kambesis

In 1994, the Survey and Cartography Section appointed a special committee to develop a set of standards for judging electronic entries in the NSS Cartographic Salon. The Committee has come up with a tentative set of guidelines for this years judging. It is the purpose of this forum to review the guidelines used this year, discuss their effectiveness (or lack of) and to get input on how to improve the guidelines for future NSS Cartographic Salons. This will be an open discussion - suggestions and critique are welcome.

**1996 NSS CONVENTION ABSTRACTS**  
**(Salida, Colorado)**

**Roundtable Discussion of Computer-Aided Drafting (CAD) Techniques for Cave Cartography**

Bert Ashbrook

The use of Computer-Aided Drafting (CAD) in cave cartography will be discussed among the participants. The discussion will focus on the use of CAD to generate paper ("Stage-3") cave maps and will be generic to all CAD programs. Anyone with a working knowledge of CAD is encouraged to participate.

Concept and techniques discussed will include input of raw survey data, the importation of previously reduced survey data, loop closure or data modification after the drafting process is complete, drawing of passage walls, use of symbol libraries, insertion of passage detail, construction of cross sections, layering systems, three-dimensional drafting, role of scale in the drafting process, creation of specialized maps, elements of artistic talent and style as applied to CAD cartography, and the impact of CAD on the surveying process.

**Demonstration of Computer-Aided Drafting (CAD) Techniques for Cave Cartography For Non-Computer Users**

Bert Ashbrook

The use of Computer-Aided Drafting (CAD) for cave cartography will be demonstrated either directly and/or by video tape. The demonstration will involve creation of a paper ("Stage 3") cave map without manual drafting. The specific software program demonstrated will be AutoCAD, but the technique shown will be generally applicable to any CAD program.

Techniques demonstrated will include use of prototype drawings, the direct input of raw survey data, the importation of survey data reduced by other computer programs, the depiction of cave walls, the use of symbol libraries, the insertion of passage detail, construction of cross sections, limited use of three-dimensional capabilities of the software, and output of the finished map onto paper.

**Virtual 3-D Walkthrough of a Cave**

Hubert Crowell

It is possible to build a 3-D image of a cave passage from photographs, and have the photographs attached to the wire frame computer model. It is also possible you could get paid for doing this!

This talk will cover the procedures and problems of creating a walk-through, 3-D model of the cave complete with formations and the ability to move around the cave. The software and training video cost will be discussed as well as the more expensive 3-D Studio software required to merge the photographs with the wire frame models.

We will discuss the hardware and the other expenses needed to create these models. Contact names and Internet addresses for more information will be provided.

**The Cart Salon: Where Should We Go From Here**

George Dasher

There has recently been a discussion of the effectiveness of the Cartographic Salon, which is one of the eight BOG-sponsored salons held annually at each NSS Convention. This open discussion is an attempt to answer some of these questions.

First are the questions concerning the Salon itself. These include: Do we need additional judging criteria changes? Do we need additional map categories? Are we moving the "NSS-approved Map" too far in one direction? Should we discontinue the Salon?

Second are the questions regarding the recognition of the Society's Cartographers. These are: Is there any way we can get more Society recognition for cartographers with the Salon? Without the Salon? What about those incredibly good cartographers who have never won a medal?

Lastly, there is a problem that I am becoming burned out on coordinating the Salon. My problems are: There is an immense amount of work required at each convention, a dearth of vacation time so that I no longer wish to attend each convention, and that I do not like being tied to the convention and unable to visit those nearby areas which I have never seen and which I will probably never again

have a chance to visit. All of this is just plain wearing me out. Questions and solutions here include: Is there anyone else who wants to take over the Salon? Maybe the right thing to do is elect a rotating chairman?

### **Methods to Facilitate Faster Sketching**

Mike Futrell

The speed of the sketcher more often than not determines the speed of the survey crew and, thus, the amount of passage mapped during the trip. Methods for increasing the rate of sketching fall into two categories: devote less time towards non-sketching activities, and simply sketch faster.

The first point seems obvious. Traveling, eating, talking, and digging are non-sketching activities. Standing around, looking at rocks with a book and pencil in hand is also a non-sketching activity – if the pencil is not moving, you are not sketching. Clean hands, teeth marks on the book, bruised elbows, and the ability to efficiently organize a crew are some indicators of a speedy sketcher.

### **The Berkshire County, Massachusetts Cave Survey Project: An Introduction and Status Report**

William D. Howcroft

The small, marble caves of Berkshire County, Massachusetts represent one of the first focus areas of organized caving in the United States. Despite over 50 years of exploration, these caves have remained largely unsurveyed until recently. A systematic survey of all “significant” solution caves and holes, otherwise deemed to be historically relevant, has been conducted for the purposes of documentation and publication. After three years of effort, the project is estimated to be approximately 80% complete with a total Grade 5 survey length in excess of two mi. Included within this figure is Great Radium Springs Cave, New England’s second longest solution cave. Pettibone Falls Cave, previously assumed to be Massachusetts’ longest cave, has been reassigned to a fourth place position.

### **Computer Graphics -A Freehand Way to Generate and Display Your Cave Maps**

Bob Richards

Cave cartographers will be replacing pen and ink with mouse and monitor as home PCs and graphics software packages become cheaper and easier to use. The use of FreeHand software as a fundamental drawing tool is just one such package available to cave cartographers.

Regardless of how powerful an illustration package is, it won’t be useful if you can’t draw with it. FreeHand enables you to draw pristine line art and smooth-as-silk technical drawings. Tasks that use to be exceedingly nerve-wracking or downright unlikely 10 years ago – like getting two thick pen lines to meet and form a perfectly sharp or smooth corner are a breeze now. With very little effort and not much in the way of experience, one can be drawing cave maps that would have made you bleed, sweat, and cry – were you to approach the task using traditional drafting tools.

FreeHand works its precision magic by looking at artwork in terms of objects, which are independent, mathematically defined lines and shapes. For this reason, drawing programs are sometimes said to be object-oriented. Understanding how one’s object your cave map is entered, set-up and executed using a variety of FreeHand tools is essential in creating a successful computer generated cave map.

### **Effects of Blunders on Survey Accuracy**

Fred L. Wefer and Rob Kolstad

A useful way to classify survey errors is based on the predictability of individual error and the statistical distribution of a large number of errors. This yields three basic error types:

Random Errors are not predictable and are caused, e.g., by rounding measurements, the limited graduation on the instruments, etc. They are typically small and normally distributed.

Systematic Errors are predictable, hence correctable. They are caused by instrument misalignment, and personal tendencies, for example. They are typically small and follow a pattern.

Blunders are not predictable and have an unknown distribution. They are caused by cold, fatigue, and sloppiness, for example. They typically occur



infrequently, follow no specific pattern, can be of either sign, and of almost any magnitude. Seven types of blunders have been identified and studied.

Loop closures are often used to determine survey accuracy. To explore error attributed to instruments or techniques (vs. blunders), we created a model of a typical cave that was then 'surveyed' perfectly.

These perfect survey numbers were corrupted to simulate standard instruments (e.g., 1° azimuth accuracy). Loop closure results demonstrated an 'average loop closure error' due to instruments. Finally, the observations were perturbed using various blunders. Loop closure errors were again studied.

Blunders are difficult to find and nearly impossible to correct. The best strategy is to anticipate and prevent them from happening. Some techniques for obviating blunders are: use equipment graduated in degrees, use an azimuth compass (not bearing), paint over the percent grade scale, set declination to zero and leave it, follow good survey team procedures, use fore and back shots, verify computer input, compare the plotted traverse line with the sketch, and learn all the positions on the survey team.

## **1997 NSS CONVENTION ABSTRACTS (Sullivan, Missouri)**

### **Fiber Optic and LED Illuminators for the Suunto Compass**

Roger V. Bartholomew

An illuminator for the Suunto compass dial has been developed from a fiber optic cable, a specially designed aluminum block to position the fiber optic cable output tip, two AA cells, a common flash light lamp, a toggle switch, a wood block and some electrical tape. The fiber optic cable is long enough to prevent magnetic deviation of the compass needle by the electrical components. The aluminum block requires one 6-32 threaded hole in the Suunto body and is designed not to block the centerline of the Suunto case so that the one eyed sighting method can be used normally. The compass with the aluminum block will fit in the Suunto case.

A self-contained illuminator for the Suunto clinometer has been developed from a green light

emitting diode (LED), a plastic right angle bracket, a 3 volt lithium button cell, a micro switch and some 5 minute epoxy. The micro switch is oriented downward so that the thumb holding the bottom of the clinometer in the usual manner can operate it. The unit can be taped or glued onto the clinometer case and it does not block the centerline of the case. The compass with both the LED illuminator and aluminum block described above for a backup will fit in the Suunto case.

### **Map Sheet Size and Layout Standards**

Arnie Weisbrot

Identification of folded map reproductions is a problem. Consider all the map packets ever published in caving books or convention guidebooks. The first thing most cavers do is write the cave name on the outside of the folded map. Furthermore, nonstandard paper sizes create considerable difficulties with storage of original maps as well as reproduction. These problems can be eliminated by standardizing the map media size, the labeling methods, and folding techniques used. This paper describes the American Society of Mechanical Engineers (ASME) Standards Y14.1 and Y14.1m. They are both American National Standards that fully define drawing media sizes and placement of various label information. The paper also describes techniques of folding outside of the map. This small effort by cartographers will make life a little easier on users of our cartographic works of art.

### **Mapping Equipment for Wet Caves**

Philip L. Moss

For many years cavers have been struggling with fogging instruments and soggy paper. There is no need to do that anymore. Suunto has inherently waterproof (prismatic) compasses and clinometers. The Silva 80 compass is inherently waterproof and floats. Brunton has two factory-waterproofed compass and clinometers. Rite in the Rain ® paper or equivalent is what most cavers have used for mapping in wet caves. Avery Tear-Proof paper for copiers is much better. It is indestructible (in cave terms) and you can create your own template for data. The Avery Tear-Proof paper unfortunately is no longer produced. You may be able to find old stock. I have also tried Nalgene Poly-Paper. It is

quite impervious to water but it does not hold pencil marks well in water.

### **Intermediate Cave Surveying• Tips and Techniques**

Robert B. Hoke

This presentation discusses a number of relatively simple tips to improve the speed, accuracy, and efficiency of a survey team. The tips only cover the setting of stations, reading the data, and recording the data in the survey book. The art of sketching is beyond the scope of this paper (and of the author). The material is presented at an intermediate level, with the assumption that the listener has been on at least one survey trip and has a general idea of how a survey operates and knows how to use the Suunto compass and clinometer. Brunton compasses appear to be a dying breed and are not covered. A handout summarizing the tips will be available.

### **An Inventory of Cave Survey Software**

Mike Yocum

This session will briefly review some current basic features of cave survey software, including: CAPS, CavePlot, CaveView, CMAP, CML, CSurvey, Compass, Karst, Pitter/Plotter, On Station, SMAPS, SpeloGen, Survey (Neads), Survey (Palmer), Survex, TopoRobot. Vectors, Walls, Win CAPS, WinCML, Win Compass, and WinKarst.

## ***1998 NSS CONVENTION ABSTRACTS (Sewanee, Tennessee)***

### **SpeleoMeshing: A Technique for High Definition Cave Surveys**

Greg Passmore

This paper describes a set of novel computer techniques for cave and mine mapping which are collectively referred to as SpeleoMeshing. The process yields detailed volumetrics, dense meshes for structural finite element analysis and photo-realistic rendering. The techniques are low cost, high in accuracy, and suitable for use on personal computers.

The process is composed of three steps: collection of passageway profiles, conversion of the profiles into 3 dimensional models and, optionally, collection and application of texture maps on passageway walls for photo-realistic rendering.

The first step of the process uses a simple pocket laser to outline each passage profile along survey lines for photographic capture. The photograph is subsequently digitized and used to calculate passage profile axiometric distances. In the second step, the resulting axiometric passage profile data is extruded between profiles into a 3-dimensional wire frame mesh. This wire frame mesh data is suitable for high accuracy volumetric analysis and for structural finite element analysis. For high quality rendering, a third step, the photographs of passageway walls are taken for color and texture definition. The resulting photographs are then texture mapped onto the 3-dimensional model and computer rendering techniques are used to produce near photo-realistic renditions of the cave.

This paper will present the details of the process, a description of the tools needed, and examples of computer imagery resulting from SpeleoMeshing.

### **Subsurface Geologic Mapping and Color Digital Cave Cartography**

Paul Burger

To date, most of the uses of color in digital cave cartography have been limited to the production of photographs and other graphics on maps, or to portray streams and other gross features. This talk focuses on the use of color to present information such as bedrock geology, unconsolidated cave fill, and floor detail. This type of detail can be easily understood by non-geologist cavers, and can be easily added to cave maps by non-geologist-cartographers. The use of color to portray information beyond what we as cavers and cartographers normally put on our maps has far-reaching potential for archaeology, paleontology, hydrology, and geology.

## **Compass, Autocad, CorelDraw! and Arcview: Lessons From Sequoia and Kings Canyon National Parks Digital Cave Cartography Project**

Joel Despain

This session will present a discussion on the successes and failures of the many aspects of the Sequoia and Kings Canyon digital cave cartography project. These maps, many of which include data bases tying specific features to survey stations, may represent a slightly different approach to cave maps. This approach can be a powerful tool for cave specialists and managers in both defining and illustrating management plans, in storing and displaying biological inventory and monitoring results, and in the documenting of cultural and mineralogical features. However, this approach is not without its problems, which may include too many trips to delicate cave areas, time consuming initial drafting, and acquired file conversions.

## **A Versatile Rangefinder**

Dale J. Green

Optical range finders based on the parallax method are almost totally worthless in the cave environment because of low light levels. Even with powerful (heavy and bulky) lights, converging the illuminated images does not produce satisfactory results. However, if an object at the distance being measured is illuminated with a spot from a laser beam, the result is astonishingly accurate. Using an instrument with a lens separation of 4 inches, repeatable accuracy of 1 inch is possible up to about 20 feet. Accuracy degrades to 2 inches at 30 feet, 1/2 foot to 50 feet, 1 foot to 90 feet, and about 5 feet up to 150 feet (if you can see the spot). Using this instrument it is possible to make accurate, non-invasive measurements to inaccessible or environmentally sensitive areas.

## **Freezing in Colorado: Techniques for Surveying Extremely Cold Caves**

Hazel A. Barton and T. Evan Anderson

Palmer Lake Ice Caves are a talus system in the foothills of the Rocky Mountains, forming part of an aquifer which supplies the nearby town of Palmer Lake. The heavy volume of water through the

system makes survey trips easier during the winter, when the streams are frozen. Unfortunately, winter causes its own problems. The cave lies at the bottom of a thermocline valley, with multiple entrances receiving little direct sunlight. As a result, the winter temperatures in the system drop below 20°F, cold enough to freeze your pack to the floor.

These severe conditions have prevented successful surveys of the system in the past. We have found some techniques which are allowing a more successful survey. Our observations include the useless nature of heated socks, how a woolly hat increases team moral more than promises of only one more shot, and a thermos of hot tea is great. More serious problems include sensitive frostbite injuries and the contraction of the metal in suuntos, causing them to 'freeze-up' in this environment. Despite the severe cold, we have encountered gorgeous ice formations and discovered that a linear distance of 30 feet on the surface corresponds to 1,200 feet underground. The fact that the lowest and highest entrances of the system are more than half a mile from each other, and the nature of the intervening cave is complex and multi-leveled, indicate that if the survey can be completed, Palmer Lake will rank among the longest granite caves in the world.

## **Automatic Underwater Surveying and Mapping**

Fred Wefer, Barbara am Ende, and William C. Stone

In October, 1998 the U. S. Deep Caving Team will field an expedition to Wakulla Springs, a show cave in The Edward Ball Wakulla Springs State Park south of Tallahassee, Florida. The objectives are to continue the exploration, survey, mapping, and scientific study begun in 1987 by The Wakulla Springs Project and continued by the Woodville Karst Plain Project. Wakulla Springs is an underwater cave exceeding 5 km in length and 100 m in depth.

Surveying will be done automatically by a Digital Wall Mapper (DWM) mounted on a Diver Propulsion Vehicle (DPV). The DWM uses an inertial navigation system for determining the position and orientation of the DPV and a sonar device that simultaneously measures thirty-two wall distances for determining cross sections; Data is

gathered several times per second, and the resulting spacing of wall points being a fraction of a meter.

Within the DWM, the data from the inertial navigation system, the sonar device, three pressure sensors, and a thermometer is stored in an on-board computer. When the DPV returns to the surface the data is downloaded to a Personal Computer (PC). The PC reformats and writes the data to a zip disk that is then transferred to a Silicon Graphics workstation. Nine separate programs, written in ANSI C and using OpenGL for graphics support, comprise the software suite. A three-dimensional interactive cave map is produced with minimal human intervention. This paper describes the hardware and presents some details of software being employed.

The following abstract is to accompany the series of maps produced by Joel Despain. There not be a formal presentation directly based on this abstract, but Despain will present a related paper on the mapping project that produced them during the Survey & Cartography Session.

### **The Crystal Cave and Sequoia and Kings Canyon National Parks Cave Cartography Project**

Joel Despain

In recent years, the cartography salon at the annual NSS convention has seen steady increases in the content, layout, and presentation quality of cave maps. During this same period, a rise in the use of geographic information systems (GIS) by land management agencies, local, state and federal governments, and universities has revealed that maps are much more versatile tools for the storage, display and analysis of spatial information than may have been previously realized. The Sequoia and Kings Canyon Cave Cartography Project seeks to integrate aspects of standard cave cartography and data bases into a cave GIS program for the inventory, monitoring and analysis of mineralogical, geological, cultural, infrastructure and biological information. The project also asked the questions, "What can be displayed on a cave map?" and "How can these maps further the understanding and management of park caves?". A key component of the project was the drafting of maps on a computer using a powerful graphics package (CorelDraw!). This allows such aspects of the maps as the cave

walls to be copied repeatedly to create new maps and displays. A final aspect of the project has been the integration of caves within the landscape of Sequoia and Kings Canyon National Parks. These maps were produced using Compass, Cave Tools Extension and Arcview (the most popular GIS program) software packages.

## ***1999 NSS CONVENTION ABSTRACTS (Twin Falls, Idaho)***

### **Creating a Successful Computer Generated Cave Map with FreeHand**

Bob Richards

As home computer hardware and software becomes cheaper and easier to use, graphics software is replacing the manual cartography methods used by cavers in the past. The use of FreeHand software is one such package available to cave cartographers. Understanding how to set-up and execute using a variety of FreeHand tools is essential in creating a successful computer generated map.

FreeHand is an object oriented drawing application that is robust and boasts many more features than the original version that first appeared 12 years ago. Cross platform and menu driven, the latest version, FreeHand8, enables you to draw high quality cave maps and graphics. Creative tools like freeform tool and reshaping tool allow you to edit paths interactively without using Bezier control points. Transparency effects, blends, shadow tools and graphics hose are just a few of the new features that can give your cave maps a professional look.

Computer generated maps have the advantage of easily adding color to a cave map. Proper use of color can add visual impact to your map. The use of color is added quickly and easily with graphics software. As more cavers start using FreeHand and other illustration programs, computer generated maps will be the preferred choice and method to draw and display cave maps.

### **A New Cave Surveying Instrument**

Ted Steinke

Because of the unique circumstances that are presented in a cave setting, cave surveyors have

selected from the broad spectrum of possible surveying instruments only a few which experience has shown seem to work better. The typical cave surveying instrument is one that is durable enough to survive the rigors of the cave environment, is hand-held and not very easy to use because of the conditions of the cave environment, and is not very accurate because of the constraints of design that are imposed by ease of use and durability. A new cave surveying instrument has been designed which reduces instrument reading error and at the same time improves the ease of use of the instrument. This new instrument allows the surveyor to concentrate separately on each of the demanding tasks that make up an instrument reading. To accomplish this separation of tasks the new instrument is mounted on a tripod. The instrument is aligned to the station target using a laser. The instrument is leveled to eliminate out-of-level azimuth reading errors. Separate readings are made for azimuth and vertical angle. This new instrument is easy to align on the station target and to check that it remains on target. It allows the surveyor to be comfortable and to get in the right position to read the instrument correctly. It allows the instrument to be properly illuminated during reading. And it allows a second reading of the instrument or a reading by another person.

### **The Development of a “Grid-Style Form”: A New Way to Combine Cave Inventory with Cave Survey**

Carol Vesely and Greg Stock

Despite the diversity in objectives, forms, procedures and data reduction techniques, there are four basic types of cave inventory methods: 1) “whole cave, open-ended methods, 2) “whole cave, checklist” methods, 3) “location-based, open ended” methods, and 4) “location-based checklist” methods. Each of these methods has its advantages and limitations. In the process of developing a cave inventory system for Sequoia and Kings Canyon National Parks, we have designed a new style of cave inventory form that has multiple advantages over many of the methods currently in use. Our “location-based, grid-style” form is simpler and easier to use than standard “checklist style” forms. The grid-style form also facilitates the detection and recording of resource information in the cave and the data transfer and manipulation afterwards. Using

this form, it is easy to combine cave inventorying with cave surveying or to return and inventory the cave after the mapping is complete.

### **Incorporating Cave Survey Data into a GIS**

Bernie Szukalski

GIS systems have long been used for the management and analysis of various kinds of data. Several methods and tools are now available to import cave survey data into GIS software packages such as ArcView GIS. In addition to simple conversion to GIS data sources, cave survey data must also be registered to the coordinate system of the underlying GIS database. Once imported and registered cave survey data can be used as another thematic layer in the GIS database for query and analysis. Software such as ArcView GIS presents unique ways to manage and visualize cave survey data, as well as link cave survey data to other information, such as biologic, archeologic, and photographic inventories.

### **SpeleoMorph -- Computer-assisted Cartography**

Steve Reames

As computer-assisted drafting becomes more popular with cave cartographers, the problem of entering and manipulating sketches becomes problematic. The optimum solution would be to have a computer program that would scale, rotate, and move the sketch on the computer to match the entered data. SpeleoMorph is the first program to fully automate this process. This talk will discuss the Kolstad Algorithm, which is the key for achieving the non-linear transformations required, and will present the results from the SpeleoMorph program on a one-mile long cave system.

### ***2000 NSS CONVENTION ABSTRACTS (Elkins, West Virginia)***

### **Carto, a Software Tool for Cave Cartography**

Ralph Hartley

Carto is a tool intended for use by a cave cartographer. It is primarily intended to allow the

preparation of conventional two dimensional maps in electronic form. The program has two main parts, a morphing system and a cad system. The morphing system takes as input processed survey data and scanned images of the in-cave sketches. The user marks the points on the image that correspond to stations and the program stretches the image so that the stations appear at their surveyed positions. Superimposing the morphed images produces a composite sketch that can serve as a working map. The cad system can then be used to “trace” over the sketch with standard map symbols, as well as user defined symbols. The cartographer can then experiment with different layouts, and either print the final map or distribute it in electronic form. Changes in the survey data (due to closing loops etc.) can be automatically reflected both the composite sketch and in the map symbology. A demo of the current state of development of the tool will be given. Carto executable and (java) source is available free of charge from <http://www.psc-cavers.org/carto>.

### **Drafting a Simple Cave Map Using Vector Drawing Software (Demonstration)**

John Ganter

Many cavers who use computers still draw maps manually. Ink on drafting film remains fast and effective for large maps, but drawing software can save significant time for small maps that have a lot of repetitive text. So what is the learning curve like and how do you get started? I will walk through a simple map drawing demo. First we will open a TIF file from a pencil-drawn draft map that has been scanned. We'll drop this on a “background layer” to trace over. Then we will switch to a “drawing layer” and trace the draft using the Bezigon tool. Finally we will add some text and move it around for the best layout. And the map is done. If there is time, we will look at Styles and the Graphics Hose, both of which can greatly increase productivity. I will use Macromedia Freehand, but the concepts demonstrated apply to Adobe Illustrator, CorelDraw, and other similar products.

### **High-Precision Surveys with a Brunton Compass**

Arthur N. Palmer

A Brunton compass must be tripod-mounted to meet its full potential. With care, readings can be interpolated to 0.1-0.2 degree with a magnifying glass. Sighting ease and precision can be improved by optical tricks, customized tripod mounts, sharpening the pivot, and sharpening the needle point with a shaped dab of lacquer. Older designs without magnetic damping have more precise needles. The compass must be calibrated to true north, preferably by sighting on Polaris and correcting for time and latitude. Correcting for needle eccentricity can reduce error considerably. With a transit, a compass course with at least 4 radiating lines is staked out, and a sinusoidal pattern of discrepancy in compass readings indicates the eccentricity. Without this correction, average closure errors are about 0.1% over multiple-station loops at least 500 m long. To level the ballfield, Brunton entries in NSS survey contests have omitted the eccentricity correction. This correction reduces closure errors to within 0.05%, as shown by numerous loops in cave and surface surveys. Tripod mounting minimizes deflections caused by metal parts in helmets, eyeglasses, etc., and steeply inclined shots can be made accurately. Alternate foresights and backsights are most convenient, but repeated readings are required to catch blunders. These methods are not suited to all conditions, but surprisingly difficult terrain can be negotiated. They are best suited for specialized purposes, such as geologic mapping or running base lines through major passages.

### **How Accurate are Our Cave Surveys?**

Robert Thrun

In one of the earliest papers on cave survey errors, Denis Warburton compared the actual loop misclosures in cave surveys with theoretical expected errors. Following this lead, the CMAP survey data reduction program does a similar comparison. For this study the BCRA Grade 5 error specification was used instead of the CMAP defaults. The BCRA grade is the only standard that has a widespread acceptance, at least in some countries. The most informative plot seems to be error ratio versus traverse length on a log-log plot.

The plots consist of a cloud of points that can be used to judge a survey's accuracy, or at least its internal consistency. Many cave surveys of different types were studied. No survey met the expectations of the BCRA specification, though a few were close. A typical survey might have 2 to 4 times the Grade 5 errors. Poor surveys have 5 to 7 times the BCRA errors. The dispersion of the clouds was always wider than would be obtained from a single random error distribution. It may be possible to characterize the accuracy of a survey from the shape and size of the point clouds. The amount of adjustment or percentage adjustment are possible alternatives to error ratio for characterizing survey accuracy.

### **Reflectorless Total Station Survey and Three Dimensional Modeling of LickCreek Cave**

Kevin L. Carriere and William F. Teskey Ph.D.

Reflectorless Total Station high precision survey technique was used to survey the ceilings and breakdown piles in the Rain and Cathedral Rooms in Lick Creek Cave, Cascade County, Montana. The survey employed a single baseline of 57.691m in the horizontal plane, by 26.743m in the vertical plane and utilized a single total station closure technique for stations referenced to the defined baseline. Point data were collected at approximately 5 degree intervals. A pseudo-random data collection technique was employed to normalize the differential distribution of sample point densities collected using the semi-systematic method. Horizontal and vertical circle closures for control network stations were within 3mm +2ppm making Least Squares Adjustment of loops unnecessary. Visualization of room geometries employed Delaunay Triangulation minimum distance algorithm based sub-routines in both Matlab 5.1 and Arc/Info 7.6. Triangulated irregular networks (TIN) were created for both ceiling and breakdown pile geometries. From the TIN's, plan view contour maps were rendered in Arc/Info 7.6 and three dimensional volumetric representations were rendered using a grid normalization and iterative smoothing algorithm employed in Matlab 5.1. The resulting models accurately represent the rooms macro-morphologies. Employment of the technique facilitates the survey and volumetric representation of large cave rooms, and shows

promise for near real-time three dimensional mapping of cavernous karsts.

### **Visualization of Cave Survey Data in 3D Using ArcView GIS**

Bernie Szukalski

ArcView GIS is a popular desktop GIS used by Cave and Karst Managers to store and manage cave survey and inventory data as well as perform GIS analysis. The ArcView GIS 3D Analyst extension provides additional tools and capabilities that can be used to visualize cave survey data and other GIS layers in 3D. Several methods and techniques are available to incorporate cave survey data into the 3D Analyst, including surface drapes, direct 3D data conversion, incorporation of 3D DXF files, model construction using 3D panels, and other methods. An overview of current approaches and techniques will be presented, along with a discussion of issues and shortcomings that future work will need to address.

### **Wakulla 2 Expedition--3D Mapping**

Barbara Anne am Ende

During the 3 month Wakulla 2 Expedition, a total of 10 million wall points were imaged within Wakulla Spring, FL (averaging about 100m water depth). The total distance of passage that was digitally imaged was 6,409m, however, multiple passes were made through the same passages. Mapping missions resulted in traversing 21,256m of passage.

The Digital Wall Mapper (DWM) was designed and built for this expedition and has 32 sonar transducers spiraled around the front end which measure the distance to the walls 4 times/second. An inertial measurement unit keeps track of the location of the mapper using ring laser gyros and accelerometers. Nickel metal hydride batteries power the electronics as well as the motor that propels the unit through the water. The DWM is about 2m long and weights about 150kg. It is neutrally buoyant and balanced to rest horizontally in the water.

The sonar produced a dense, precise image of the passage walls with detail unavailable through traditional forms of survey. The ring laser gyros accurately recorded angular changes by the DWM. The accelerometers built up error and mapping

paths were significantly corrected by 38 cave radio locations. Additionally, passage locations were adjusted by matching sonar profiles.

The point cloud of wall points makes a complete map as is. However, the next step is to mesh the points into polygons to form solid walls and permit digital fly-throughs of the cave.

## ***2001 NSS CONVENTION ABSTRACTS (Rock Castle County, Kentucky)***

### **Cave Illustrator - An Adobe Illustrator Plug-in for Cave Cartography**

Jim Olsen

While first learning to create digital maps, the author noticed the complexity in transferring survey data to the art program used to draw the map. It involved entering the data into Compass, or some other cave survey program, then exporting a bitmap or DXF file. This file was then scaled and aligned with the current drawing. Every time a new survey trip returned, a new file would need to be exported from the cave survey program, scaled, and aligned. There had to be an easier way! This led to the idea of a project that allows the direct importation of Compass format data into the popular Adobe Illustrator drawing program. This simplifies the creation of maps, since the plot is updated without exportation and subsequent alignment. Further, it has advanced features and capabilities that are only possible from within the art program. The survey data can be viewed as raw data in a standard Adobe dialog, while simultaneously being highlighted within the artwork itself. Station labels, line color, etc. can also be manipulated and selected. Further, features such as 'undo', 'select', etc. all work seamlessly between Adobe and the plugin. The overall result of the effort has been a dramatic increase in the ease and speed at which 'up to the minute' maps can be created. This session explores the results of the work so far, and will elicit feedback for desired features from the audience. A live demonstration of the software, in its current form, will be presented

### **Digital Cave Data Collection**

Aaron Addison

The last ten years have seen a great deal of effort .towards automating various aspects of cave survey. Data collection has largely been ignored during that time. The challenges of digitally collecting information in a cave environment are many and wide ranging. With evolving technology, it is now realistic to collect both survey and inventory data in-cave, digitally.

This technique uses an ordinary PalmPilot(tn) to collect the data and then transfer data to cave survey programs such as Compass and Walls. Discussion will also address ways to "cave proof" the data collection device.

### **Handheld Laser Rangefinder for Cave Survey Distance Measurements**

Roger V. Bartholomew

The Leica Disto Classic handheld laser rangefinder sends out a continuous red laser beam when turned on. This is directed to any surface or diffuse (not mirror) reflection target plate and the measurement key is pressed. A pulsed laser signal is sent out and if enough laser light is reflected back, the distance reading appears on a LCD display in either meters ( to 0.001 m), decimal feet ( to 0.01 feet) or feet and inches ( to 1/16"). Specifications claim an accuracy of + or - 3 mm. The Disto Classic mounted on a tripod gave a reading of 98.35 feet as compared with a reading of 98.36 feet from a K&E Whiteface Steel Tape. The steel tape has been heavily used and could be stretched and could be further elongated by the 85 deg F. temperature during the measurement. Ordinary range is from 0.3m (1 foot) to over 100 m. (400ft.). The unit is 6 3/4" x 1 19/16" x 2 19/16" and weighs 13 ounces with 4 AAA cells. The Disto Classic is good enough to do station to station distances with a precisely positioned target plate. It can be used to do up/down/left/right distances at a station or do precise cross sections by pointing at the cave walls with a clinometer at each station. For surface surveying, a long strip of SCOTCH LITE Reflective trim and a target plate ringed with SCOTCHLITE enables one to see the continuous red laser spot for targeting.



## Current Cave Surveying Standards

Barbara Anne am Ende

I am conducting an on-going poll of cavers to determine the current state of surveying quality. The poll asks five questions:

- 1) How often do you take backsights in addition to foresights?
- 2) If you take backsights, how close must the agreement be for you to not retake the measurements—azimuth and inclination?
- 3) How close must the instrument and light be to the station?
- 4) Do you have any loop closure data?
- 5) How many days per year do you survey?
- 6) Where are you from?

Most respondents are from the United States, however, some are from other countries. The poll should not be considered random and is probably skewed toward more careful surveyors who are more likely to respond. However, the poll is intended to be a starting point for understanding how surveys are conducted in the real world. Additional questions that remain to be answered include knowing how often those who take backsights find that they need to re-do their readings. Most respondents simply answered yes or no to having loop closure data. Studying the actual loop closures relative to the frequency of backsights may be useful in determining the potential increased accuracy of backsights.

## Current Status of Meshing of the Wakulla Spring Point Cloud

Barbara Anne am Ende, Javier Bernal, and Christoph Witzgall

A point cloud of 10 million wall points (thinned to 3 million) was gathered in 1998-1999 during the Wakulla 2 Expedition. The data was collected in the water-filled cave by a custom-designed sonar Digital Wall Mapper (DWM). Meshing the point cloud into a polygonalized surface remains a challenge. Problems to be overcome include: 1) The point cloud is unstructured data rather than data collected in grids. 2) Branching passages are challenging to write algorithms to interpret. 3) Real data contains noise that must be ignored. 4) The multiple data sets required registration. The automated portion of the registration was nearly perfect, but the manual registration was not as good giving a “thickness” to

the wall positions. The current process of meshing begins by figuratively placing the point cloud in a box. The outside of the cave point cloud is meshed from points on the box, while the inside of the cave is meshed from the original DWM position within the cave. Parameters such as the length of “legal” polygons are used to refine the meshing. Where the data is thin, such as where the mapper’s “viewing” of distant walls or the floor was blocked by obstructions, a longer length must be used to create the proper mesh. However, too short of an acceptable length results in erroneous polygons forming at branches in the passage. We envisage that the current technique will solve the meshing problem, but requires extensive experimentation to achieve total success.

## 2002 NSS CONVENTION ABSTRACTS (Camden, Maine)

### Surface Survey Tools for the Suunto Compass

Roger V. Bartholomew

A tripod for the Suunto compass employing a vertical center pole and two legs at 90 degrees to each other was developed. The vertical center pole is a precise vertical target when the Suunto is at another station backsighting to the tripod. The top of the tripod is a half-inch thick wood disk with a radius (1 11/128 inch) equal to the distance from the Suunto compass pivot to the target end of the case. When the Suunto is placed on the wood disk with the target end of the case even with the edge of the wood disk, the compass pivot is centered on the vertical center pole of the tripod. A separate wood cylinder (1 11/128 inch radius and 1 3/4 inch height) with a 1/2 inch wide by 7/8 inch deep slot across the top, allows sighting the compass underneath the case through the slot when it is placed between the disk top and the Suunto.

Another tripod, with a 3 x 14 x 1 1/2 -inch wood top having a 3/4 inch wide x 7 inch slot for a pendulum, allows a Suunto and pendulum to be shifted left or right when backsighting a previous station. The Suunto rests on a 3 x 3 x 1 1/2 inch sliding wood block with a slot for sighting underneath the case and a pendulum string centered on the Suunto compass pivot.

A laser rangefinder and several vertical poles with levels allow solo surveying with the tripods.

### **Using a Disto Laser Range Finder to Survey Caves in Belize**

David Larson and Brian Pease

The 2002 Barton Creek Cave Mapping Project used two different models of Leica Disto rangefinders to measure distances in Barton Creek Cave and other caves in the Cayo District in Belize. By using the Distos we could accurately measure distances between stations, and make left, right, up, and down measurements. These measurements, which would have taken hours or been impossible with a tape, took only minutes with the Distos. In one room of Barton Creek Cave, the ceiling height measured 180 feet, and we only had a 100 foot long tape. The sketchers were given accurate measurements from spray shots to the walls and speleothems, rather than estimates of distance. Many of the station-to-station distances exceeded 100 feet. Ceiling heights varied from 10 to 180 feet. Left and right measurements exceeded 100 feet in many places. The data from the Disto, plus direction and inclination data were entered into a laptop computer running Walls, a cave mapping program, to produce an outline map of the cave. The final map will be made by scanning the sketches into a CorelDRAW graphics program.

At the end of the trip we found another cave. In 90 minutes; we were able to collect survey data for 1,300 feet of cave. It would have taken all day if we had been using a tape to measure the distances. The mapping was done under the auspices of the Western Belize Regional Cave Project, directed by Dr. Jaime Awe, for the Belize Department of Archaeology.

### **A Review of Electronic Survey Tools**

Nigel Dyson-Hudson

Tools for electronic cave surveying include high-end bore hole profiling systems, to mid-range commercial tools like the Leica Disto, to a home-designed distance meter with digital compass and clinometer.

Except in rare cases, hand sketching will probably not be replaced anytime soon. A laser electronic distance meter to create a cloud of points that then

become a 3-D virtual reality model of a cave is only practical in a limited number of cases.

The Leica Disto laser distance meter can be used to take automated distance measurements, especially of a high ceiling. This was done by one of the survey teams in Breathing Cave, VA. We were able to get accurate ceiling heights of around 18m (60 ft), despite the ceiling being dark and stair-stepped. We were also able to get measurements of the width of pits that we could not cross.

A number of people have put together systems that combine a distance meter with digital compass and clinometer in one survey instrument. The capability exists to transfer the data directly into a plotting program in the cave. One may be able to create a line plot of the cave and resolve errors before leaving.

## ***2003 NSS CONVENTION ABSTRACTS (Porterville, California)***

### **Compass/Inclinometer Using Laser Pointer for Cave Surveying**

Dale Andreatta

A new device has been developed that incorporates a small laser to make compass and inclinometer use easier. The laser is used as a pointer, not as a distance measurement device. The device is a 2-piece folding unit with a laser pointer and inclinometer on the front piece and the compass on the back piece.

To use the compass, the rear half of the device is approximately leveled with the back at the "from" station, and the front half tilted so that the laser points as the "to" point. The vertical plane containing the survey points also contains the line of laser light and the axis of the compass. The compass is read in the usual manner. A telescoping extension is useful when the "from" station is on the ceiling of a passage. To read inclination, the hinge of the device is held on the "from" survey station, and the laser is pointed at the "to" survey station. The inclinometer is read in the normal manner. Two types of inclinometers were tested, an electronic version and a mechanical version. Both can be used without looking at them, and hold their readings once they are set.

The device is about 6 inches long when folded and about 2 inches in “diameter”. The device has been used in cave surveys and has performed well. The device has been tested around a 4-sided loop, and backward and forward loops have closed with about 1° of average error horizontally and 0.3° vertically.

### **Regional Studies for Underwater Caves in Quintana Roo, Mexico**

James G. Coke IV

Underwater cave survey techniques integrated with the Global Positioning Service (GPS) disclose underground drainage configurations and cave relationships in eastern Quintana Roo, Mexico. The present study area incorporates 6,300 square kilometers. Garmin II+ and Garmin V GPS receivers, calibrated for civilian applications, verified entrance coordinates at independent underwater cave systems. With Selective Availability disabled, a 12-channel receiver reports a three to nine meter Estimated Position Error at coordinate collection locations. Correlating distant cave systems by conventional land surveys in the indigenous jungle environment is problematic; those surveys exceeding 1.5 kilometers encourage GPS applications. A database of 230 GPS locations for underwater karst formations, and 74 km of land survey provide surface control points for the regional analysis.

Safety and environmental issues require underwater cave explorers amend traditional cave surveying methods. A permanent guideline, knotted at fixed intervals, is positioned in new passage during initial exploration. Survey data is collected on the exit utilizing a depth gauge and compass, while knotted segments of the guideline are tallied between survey stations. Eleven underwater caves in Quintana Roo are surveyed by more accurate methods. Taped survey lengths, compass backsights, and measuring passage attributes are means used to create these maps. A total of 91 underwater cave surveys (431 kilometers of surveyed underwater passage) are incorporated in the regional study.

Computer software converts raw cave survey data into georeferenced coordinates. Additional software manages GPS data, while calibrating topographic maps and aerial photographs.

### **Cartography of Lilburn Cave**

Peter Bosted

Lilburn is a 20 mile long, 3-dimensional maze cave that presents interesting cartography challenges. This has led to the development of a multi-level quadrangle system. approximately 90 quadrangle maps are needed to cover the entire cave. For convenience in reproduction and in-cave use, the text and level of detail are sized for 11” by 17” format, but can also be used in 8.5” by 11” format. Up to four vertical slices are made for each plan view. The slices are selected on a station-by-station basis for the best clarity, rather than strictly by elevation. A special code for each station is used by a custom plot program to decide which level(s) a given station is to be plotted on. Typically, 3 to 5 stations of overlap are used at level transitions. Each transition is given a number, and prefixed by “U” or “D” to tell the reader whether to look “up” or “down” a level for the corresponding number. A program was written on a Mac to make the line plot and borders given the code for a given quadrangle. The cave passage and details are drawn in Canvas or Illustrator. This makes it much easier to make changes than using pen and ink. Additional maps to visualize the overall cave have been made with custom software, including stereo 35-mm slide pairs. Examples of the latter will be passed around to the audience.

### **The Effects of Lava on Compass Readings**

Dale Green

Cavers mapping lava tubes well know that compass readings are not always what they should be. This is many times incorrectly attributed to the attraction of the magnetized compass needle to magnetic material(magnetite) contained in lava. However, the main causes of unwanted needle deflections are due to distortion of the magnetic field because: A) A property of magnetic material called susceptibility and: B) Magnetization of magnetite from lightning strikes. Knowing how these effects arise and their characteristics may aid the mapper in achieving better readings. Fore- and back-sights cannot correct for readings caused by distortion of the earth’s magnetic field.

## **DJVU Map Encoding for Display on the Web**

Mark Passerby

Using DJVU encoding has given the Raders Valley Project the ability to communicate visually to project participants using highly zoomable, crisp, small file size images of current working maps. Further information such as “zoom startup” and embedded hyperlinks in the image further the usefulness of this technology. To begin the process cave project participants must download a small browser plug-in that will allow the embedded images to be loaded via their web browser. Then maps both working and complete can either be scanned or opened in the DJVU editor and encoded for display on the web. Using the zoom tools in the browser the project participant can now zoom in to specific areas with very little loss of detail to focus on areas of interest within the survey. This technology opens the door to sharing maps with incredible detail and a small file size via the web.

I have been using DJVU encoding for years and this presentation will focus on the workflow process of moving scanned images and digitally saved maps to the web via an embedded DJVU image.

## **Morphing Digital Working Sketches to Line/Wall plots using Manifold 5.5**

Mark Passerby

Registering and morphing a rough digital working sketch to a line plot only accomplishes part of the complex process needed to accurately trace a final digital cave map. To fully accomplish a digitally “traceable” bottom layer requires that the passage walls from section to section match up and further that the left and right points at each station are registered and morphed along with the sketch to the line plot points. I have developed a workflow process using Manifold 5.5 to effectively accomplish this. First, working sketches are scanned and then opened in Manifold. A separate lineplot image with tics for left/right is then opened in the same project and control points placed on both images at spots corresponding to survey stations, left/right points and wall segment joining points. Using a geo-registering method that Manifold calls “Affine” the rough sketch is then morphed onto the line plot and the assembly begins piece by piece. The final result is a fully aligned and digitally traceable cave map

layer. Experience has shown that proper order in placing the control points results in consistent and highly accurate results.

This presentation will focus on examples of the workflow process and a quick demo of the actual registration of a rough working sketch segment to a cave surveys line and wall plot.

## **Computer Generated Cave Maps: What you need to Set Up and Be Successful**

Bob Richards

The art of cave cartography did not involve computers just a few years ago. Pen and ink, mylar and large drafting tables have been replaced by the mouse, monitor and software. The new techniques today are easier to use and master and they have far more precision and options for creating beautiful cave maps. Graphics software is replacing the manual cartography methods used by cavers in the past as home computer hardware and software become cheaper and easier to use. The hardware and software which are good for creating professional looking maps will be discussed in general terms. Understanding how to set up and execute using these tools is essential in creating a successful computer-generated map. The steps used to set up and create a professional looking cave map and what the map judges are looking for in the Cartography Salons will be presented.

## **Update on 3D Mapping of a Portion of Laurel Caverns, PA.**

Barbara Anne am Ende and Lars S. Nyland

In June, 2002 a portion of Laurel Caverns, PA was scanned with a DeltaSphere-3000 device built by 3rdTech, Inc. in Chapel Hill, NC. It is a scanning, time-of-flight laser rangefinder that takes up to 20,000 measurements per second. The laser is directed around the environment with mirrors and motors, capturing 360 degree panoramas that have a 150 degree vertical span at a resolution of about 13 samples per degree (in each direction). The laser measures distances to the first surface it hits, up to about 15 m away, with an accuracy of about 8 mm. To overcome occlusions or shadows, range scans are taken from multiple locations. Sufficient overlap between scans allows them to be aligned with one another during post-processing.

For each range scan, there is also a color panorama acquired with a Kodak Professional Digital Camera. A wide-angle lens is used, providing sufficient color imagery at a resolution that is close to that of the range scan. Average time for a scan is about 30 minutes. To complete the work, we spent 6.5 hours scanning from nine locations.

Post-processing has involved several steps. The color images are fused together with the range data, coloring each range sample. We use the Polyworks software tools from Innovmetric coupled with some of our own custom tools. Since our presentation last year, we will show finished alignment of the multiple data sets, a wire mesh of the data, and color images mapped to the points.

## ***2004 NSS CONVENTION ABSTRACTS (Marquette, Michigan)***

### **Tips for Efficient Cave Surveying**

Bob Hoke

This presentation describes some ways that a survey team can improve their productivity and efficiency by “working smart, not hard.” Among the techniques described are allocating tasks so that no team member is overloaded or under-utilized, defining the responsibilities of each team member, placing stations to facilitate easy shots, taking reading in a consistent order, taking advantage of geometry to make shots easier to read, avoiding reading and recording errors, testing instruments before each trip, agreeing in advance on how dimension data is to be recorded, carrying instruments to facilitate quick use, using a small flashlight to light stations for backshots, and knowing when to quit and head out of the cave.

### **An Analysis of Random and Systematic Surveying Errors**

Dale Andreatta

An analysis was performed of various types of surveying errors, with the errors falling into 2 categories, random and systematic. Random errors are errors that are as likely to be off in one direction as the other, and may be large or small in magnitude. Random errors come from instrument readability (usually on the order of 1-2 degrees) and

“blunders” which can be small or large. Systematic errors are errors that are consistently off in one direction. Systematic errors generally come from instrument offset. This analysis concentrated on compass and inclinometer readings in longer passages.

Analysis was performed using statistical methods and by numerical experimentation where 50 shots of actual survey data was taken and errors were assigned to the data. The differences between the data with errors and the data without errors were calculated.

The conclusions were as follows. Random errors caused by instrument readability consistently cancel out in longer passages. Therefore, meticulous matching of the foresight and backsight readings beyond that which serves to catch large blunders is not helpful. Instrument offsets of even  $\frac{1}{2}$  degree give much larger final errors, even if the instrument offset is smaller than the readability of the instrument. This is because systematic errors accumulate rather than cancel. Fairly frequent blunders of 10 degrees make less difference in the final answer than instrument offset. Aside from preventing major blunders, the best way to improve survey data is to carefully take into account the differences between survey instruments.

### **Survey and Cartography of Marengo Cave, Indiana**

Bob Richards

Marengo Cave is a beautiful show cave in southern Indiana that was originally mapped by the state in 1932. A new survey was done in September 2003. Using modern cartographic techniques, a more accurate and detailed map was generated. Surveying caves using laser technology and mapping caves using computer software will be discussed.

### **Enhancing Workflow in Digital Cartography**

Brandon Kowallis

While the advent of computer mapping has greatly improved the potential of the cave map, digital maps often sacrifice that timeless humanistic fluidity of a hand-drawn map for machine-like repetitions that make us say, “that’s definitely digital”. This presentation will focus on various features in Adobe

Illustrator that allow you to speed up the cartographic process while creating maps that allow a digital cartographer keep that timeless hand-drawn appearance. We will use layers to make global changes to specific features, generate brushes to cut time from drawing the minute details, and copy and manipulate forms to create repeating shapes that don't resemble computerized duplicates.

### **“Field” Cartography for the Xiangxi Expedition to Hunan Province**

Pat Kambesis

In March of 2004, a team of cavers sponsored by Hoffman Institute and The Guilin Institute of Karst and Geology assisted with field assessment for a hydrologic project which was being conducted by the Xiangxi engineering/hydrology group. The purpose of the expedition was to evaluate the Dalong Cave System and surrounding karst area for the feasibility of constructing an underground dam and a surface reservoir. Using various data reduction, plotting, 3D analysis, cartography and GIS software, field maps were generated in order to help the Chinese hydrology project group visualize the caves, karst features and topography of the area. This talk will review the methods used to produce useful field maps from basic cave survey data, GPS data, and digital elevation models.

### **Auriga, or Trading Your Survey Notebook for a PDA**

Luc Le Blanc

The Auriga cave survey software for Palm OS was originally written to assist in the development of an electronic sensor box designed to automatically acquire azimuth and slope measurements, but has now evolved into a smart survey notebook replacement for in-cave use and a lighter weight laptop replacement while at camp. Surveyors can see the cave map on screen while doing their survey, and data does not need to be transcribed later, thus preventing many blunders throughout the process. Despite the smaller screen and slower CPU of Palm devices (vs PCs), Auriga offers graphical and spreadsheet rendition of cave passages, survey stations and survey shots between them. Thanks to sessions, a concept already present in most cave survey software, surveyors can free their mind of instrument calibration, varying magnetic declination

and mixed measurement units. This allows Auriga to faithfully store survey data exactly as input, only applying corrections and conversions when computing coordinates. Several efficient design aspects provide the cave surveyor with a highly configurable and ergonomic interface, even when operating through a windowed protection box. Once back on the surface, survey data can be sent to other Palm devices through an IR beam or uploaded onto a computer and converted into common cave survey file formats via a software “conduit”. The Auriga freeware is under intensive and constant evolution; support for networks of several caves and loop closure are currently in the works, while on-screen freehand sketching of cave walls and details remains the ultimate goal.

## ***2005 NSS CONVENTION ABSTRACTS (Huntsville, Alabama)***

### **Challenges of, and Differences Between, Surveying in Commercial Caves and Wild Caves**

Carol Tideman

Surveying in a commercial cave is a significantly different environment from what most of us are familiar with when surveying in wild caves. At first glance, it would seem to be much easier. Commercial caves are generally well lit and have groomed pathways. This presentation is a study of the advantages and disadvantages associated with commercial cave surveying. Do the pluses outweigh the inconveniences encounter by the surveyors?

### **Using GIS to create The Mammoth Cave Atlas**

Aaron Addison

In the spring of 2005, over 50 years of Cave Research Foundation (CRF) exploration efforts in the Mammoth Cave area were assembled in a Geographic Information System (GIS). Among other tasks, one result of this goal was the initial prototyping and production of The Mammoth Cave Atlas. Maps from different data sources including, pencil on mylar, ink on mylar, Adobe Illustrator, and CAD formats have been combined in to one dataset to visualize the world's longest known cave system.

Work continues on this CRF project, but preliminary results indicate that GIS provides an excellent software platform for producing color sheets of various maps, scales, and themes. A base of maps depicting known cave passage are being assembled as 11x17 sheets in to the +200 page The Mammoth Cave Atlas.

### **Using PDAs in Cave Projects**

Jon Jasper

Personal Digital Assistants or PDAs, such as Pocket PC and Palms, are bringing a new form of portable computing tools to cavers. These extremely portable devices support powerful mapping applications such as GIS with ESRI ArcPAD, moving topographic maps with National Geographic TOPO!, street mapping with Microsoft Streets, and cave surveying with Auriga. The presentation will discuss the limitations and potential of incorporating PDA technology into Cave Projects.

### **High Tech Surveying---Using Ruggedized Laptops and Tablet PC's for Data Entry and Digital Drawing . . . In-Cave**

Mark S. Passerby

This presentation will focus on the work and efforts of the Zicafoose Blowhole Cave Survey Project with an emphasis on the use of ruggedized laptops and tablet PC's to enter data and digitally sketch while still in the cave! Sample map books along with a complete overview of the processes, equipment, and software needed will be discussed.

## ***2006 NSS CONVENTION ABSTRACTS (Bellingham, Washington)***

### **Survey Shot Linking Order as an Indicator of Accuracy**

Bob Thrun

Development of the CMAP survey data reduction program to handle forward references led to having versions that produced three different survey shot linking orders. If the survey network is sufficiently well connected, the different versions produce three relatively independent survey paths to any part of the survey. This small sample provides an indication

of the consistency and accuracy of our surveys. For a good survey with blunders having been resurveyed, the different locations of a station fit inside a box whose diagonal is on the order of 3 to 4 percent of the straight-line distance from the entrance. This tends to support the old rule of thumb that the accuracy of a survey is about 2 percent. Of course, the linking order does not affect the location of stations after closure adjustment, but the adjustment method does. Locations produced by least-squares and sequential adjustments differ by 0.5 to 1.0 percent. Different weighting factors in the least-squares adjustment affect the locations by less than 0.5 percent. This type of analysis is less effective for non-maze caves.

### **Baseline Information for Understanding, Managing and Protecting Caves and Karst**

Patricia Kambesis

In order to effectively manage, protect and conserve caves and karst, it is important to have basic knowledge about their physical extent, nature and attributes. Geographic data, resource inventories, and photodocumentation provide the baseline of information necessary to understand cave and karst resources. Synthesis of this information into maps, databases and geographic information systems provides the framework from which to make sound and intelligent resource management decisions. Such baseline data and information is also a starting point for scientific research. Ultimately it is research that will further knowledge and understanding about caves and karst.

### **Human Factors and Controls – Mitigation and Detection of Common Sources of Problems that Influence the Accuracy of Cave Surveys**

James D. Borden

In-cave surveys create a “perfect storm” for errors and blunders. Poor conditions, substandard equipment, and inexperienced and fatigued personnel all contribute to poor quality surveys. Thirty years of surveying in Mammoth Cave have taught us much about survey techniques and the sources of errors and blunders. Besides the often discussed, albeit general, topic of survey accuracy, we have become aware of common situation occurrences (the human factor) that have the

greatest likelihood of creating the bane of surveyors – the blunder. A good understanding of these common causes of errors, and of the in-cave survey-scenarios that can contribute to this problem, offer opportunities to not only prevent survey problems, but also to detect them during post-survey analysis. We will describe common, blunder-prone survey-scenarios; approaches that have proven to be effective in addressing them; and techniques for analysis to assist in blunder detection.

## ***2007 NSS CONVENTION ABSTRACTS (Marengo, Indiana)***

### **Roundtripping a Digital Map of Dry Cave with WALLS and Adobe Illustrator Software**

Stan Allison

Cave cartographers commonly face the problem of adjusting cave maps to changes in survey data such as loop closures and additional survey. To avoid this problem, many cartographers wait to draft a cave map until after the survey project is finished. This results in maps not being available for ongoing survey, and occasionally never being completed.

Roundtripping solves this problem by registering digital cave maps to the digital survey data. This process involves exporting digital lineplots of cave survey data using WALLS cave data management software as a Scalable Vector Graphic (SVG) document. This SVG document is opened in Adobe Illustrator where walls, detail and other map elements are created in specific layers and then saved as an SVG. When new survey data or data changes are made to the survey data in WALLS the SVG modified by Illustrator is adjusted by WALLS so that the map elements will conform to the new survey data.

Dry Cave in the Guadalupe Mountains of New Mexico is an excellent test of the roundtripping process for drafting digital cave maps. Dry Cave is an extremely complex maze cave with many loops and at least five levels. The cave map is divided into five separate maps by level using WALLS. These Dry Cave level maps are updated after each survey trip using the roundtripping process with excellent results. Over 8.9 kilometers (5.5 miles) of survey has been drafted using the roundtripping process.

### **Using Auriga: Tips and Tricks for Faster and Better Cave Maps**

Luc Le Blanc

The Auriga cave survey freeware is now an expedition-proven field tool with an ever-growing user base. Given the numerous advantages this Palm OS-based program provides (real-time graphical view of cave line plot, error detection, sketching aids, anticipation of connections, orientation of exploration in progress, etc.), many teams the world over would never want to return to a paper notebook. This presentation shall help users to better use the software by providing tips and tricks on how to document survey shots, quickly locate survey shots in large caves, sketch to scale, detect errors, geo-reference caves, locate surface features and neighboring caves and secure survey data. While targeting current users, this presentation should also be of great interest to potential users by showing the many unique features Auriga offers, both underground and at camp.

Consequently, the park has employed a variety of cave radio location techniques to correct for survey error. There are currently 38 radiolocated points that have been tied into a surface survey and or GPS locations. Although this technique has its limitations, the errors are less than could be obtained with a subsurface so the radiolocations are used as controlpoints to correct the cave survey. This allows the park to make decisions based on a high level of certainty of geospatial relationships between surface and cave features.

### **Open Data: Small Caves Example to Preserving Data on the Internet**

Howard Kalnitz

A recent look into my file cabinet revealed a sobering fact. Of the many data sets I had, a large number were from cartographers or surveyors that were no longer caving, and in some instance no longer had any links to the caving community. In several cases I was the only one with the data to undrawn caves. What would happen if I were to lose this data, either from catastrophic events, or plain indifference? Likewise, what happens to data when a caver passes away, and the family or spouse have no idea what to do with all those muddy notes.



Large cave projects are actively saving and distributing notes and work to make sure nothing is lost. I will share a similar proposal for small caves that uses the Internet to store and distribute data that can increase access, distribute projects, and warehouse, and backup data for an extended period of time.

### **Using Cave Radiolocations as a Control Grid for the Cave Survey in a Large Cave System**

Mike Wiles

Virtually all of the known portions of Jewel Cave have been mapped since 1958. This consists of over 139 miles of passages, lying beneath approximately three square miles surface area. Most of the cave has been surveyed with Brunton and tape, but the park is now regularly using Suuntos and Disto laser meters. The survey has over 24,000 stations with 423 loops.

Because the farthest point of the cave is nearly 7 miles of survey from the nearest entrance (the elevator), subsurface loop closures are not entirely adequate for determining the accuracy of the survey.

Consequently, the park has employed a variety of cave radio location techniques to correct for survey error. There are currently 38 radiolocated points that have been tied into a surface survey and or GPS locations.

Although this technique has its limitations, the errors are less than could be obtained with a subsurface survey, so the radiolocations are used as control points to correct the cave survey. This allows the park to make management decisions based on a high level of certainty of geospatial relationships between surface and cave features.

### **William E. Davies: Pioneer Cave Mapper**

Robert Thrun

William E. Davies is best known for his books *Caverns of West Virginia* and *Caves of Maryland*. He was also a pioneer cave mapper. He published the first English-language article on cave mapping in 1947. It included a list of cave map symbols that are the core of typical American symbol sets. He mapped 36 West Virginia caves in the summer of 1948. He gives only a single date for each cave,

which means that he did compass-and-pace surveys. Despite the speed, he got dimensions and angles reasonably accurate. The passage detail he shows matches that of current maps. The main shortcoming of his maps is that he did not go down every passage.

### **Advances in the Visualization of Cave Survey Data and Maps**

Aaron Addison

There have been many advances in the visualization of cave survey data and maps in recent years. This talk will be a review of the implementation of several of these new technologies on cave data. Some of the major topics include cost effective LIDAR data collection, techniques for display of cave data and maps in Google Earth, and photo visualization.

### **Using a Digital Level and Laser Rangefinder to get Cross Sections**

Robert Thrun

A SmartTool digital level and Leica Disto laser range finder, joined together, were used to get passage cross sections. One person handled the level/range finder combination and called pairs of numbers as fast as another person could write them down. The first effort was done with the instrument combination being handheld. Both the angles and distances were constantly changing, but the numbers were more accurate than estimating them. Later, the instruments were tripod-mounted. It was found that a ball tripod head was not adequate to insure that all the measurements were made in a single vertical plane. Both cross sections and passage profiles were made. The biggest difficulty was floor obstructions.

## ***2008 NSS CONVENTION ABSTRACTS (Lake City, Florida)***

### **Survey Instruments: Digital or Manual? A Field Comparison of Relative Accuracy and Practicality of Usage**

Aaron J. Bird, Rachel F. Bosch, and David A. Riggs

This project served to investigate the use of digital hand-held devices compared against manual devices

outside of traditional, professional surveying, in environments including caves. In recent years, the number and sophistication of hand-held surveying tools used in applications outside of professional surveying has increased. These tools have seen greatest use in construction and include laser range finders; digital inclinometers; and full spectrum devices outputting distance, inclination, and azimuth. Specific devices include: Leica DISTO laser range finder, Shetland Attack Pony, TruPulse 200 range finder and inclinometer, and TruPulse 360 multi-function surveying tool. In the past, non-traditional surveying has been successfully conducted using survey tapes and hand-held manual survey instruments, such as Suuntos liquid-filled precision compasses and inclinometers. While very cost effective, manual instruments are subject to a number of errors. These include recording blunders, instrument variability, and instrument reader variability. Furthermore, accuracy when using manual approaches decreases as shot distances increase. Results of this work show that the above can be largely eliminated by using digital surveying devices. The most significant finding may be that errors from instrument-reader variability are nonexistent for well-aligned shots due to the deterministic nature of making measurements with digital survey devices. There are, however, two significant downsides to digital survey tools: (1) their unreliability in harsh environments, and (2) their high cost in comparison to manual precision instruments. The key conclusions of this work are that digital survey tools applied outside of professional surveying are accurate, reliable in most environments, and relatively easy to use.

***2009 NSS CONVENTION ABSTRACTS  
(15th International Congress of  
Speleology, Kerrville, Texas)***

**Blunder Detection in Complex Survey Networks**

Peter Bosted

In the process of surveying a complex cave, there are many opportunities for errors, or blunders, at all stages of the process. This is particularly true in large, complex caves surveyed by many different teams, such as Lechuguilla Cave, New Mexico. The

author has developed software to search for the likely blunders, using the principle that multiple survey paths to the same physical point should agree with each other, within the statistical error expected for the three measurements between any given pair of survey stations. The technique is to perform a least-squares solution of the survey grid that minimizes the total adjustments needed to close all of the loops. Then, the sequences of stations that connect one junction to another are removed from the grid (by giving them a very large expected error) one at a time, starting with the one that had the large adjustment needed. Checks are made to see if the sequence in question would then close to the positions determined by all of the other sequences in the grid based on the following possibilities: a) one of the compass readings is reversed; b) one of the inclinations is reversed; c) one of the stations at the beginning or end of the sequence is different from the one in the data base; d) the inclinometer scale was in percent rather than degrees; e) one shot should not be in the sequence (for example because it was a splay shot). This procedure is repeated for all of the other sequences that need large adjustments (with adjustable criteria for “large”). An option exists to either leave the sequences already checked out of the grid, or put them back in again. A report is generated with blunders that are considered “very likely” to be true, where again the criteria for “very likely” can be adjusted to avoid too many possibilities. If the suspected blunder cannot be verified from a careful examination of the survey sketches in the relevant area, then a printout is made of each “bad” sequence in a format that is easy to use for field checking in the cave (including station sequences to get the given area from a major trail, and a list of all shots that tie-in to the stations in question). The field-checking team first checks for the likely blunders, if any are suggested. If necessary, the entire sequence is re-surveyed to find more subtle problems, such as a badly calibrated compass, magnetic cave headlamps affecting the readings, many mislabeled stations, or errors in distance measurements. The first 80 km of survey of Lechuguilla Cave included a very large number of blunders, in part due to the large number of cavers working in a given area, and also due to the lack of back-sights. The software has proven very useful in reducing the number of sequences that needed large adjustments from about 25% to less than 1% in the Western portion of the cave, and less than 3% for the entire cave. The most common blunder was

found to be incorrect labeling of survey station flags. Techniques that can be used to minimize the likelihood of blunders are listed.

### **Laser Scanning Use in Cave Contexts: The Cases of Castellana (Italy) and Naica (Mexico)**

Er Minio Paolo Cane Vese, Ro Ber Ta Tede Schi,  
Paolo For Ti

Survey in caves implies operative and logistic problems due to the position, extension and development of the cavities to be studied. Moreover, it is not possible to measure, with high level of detail, the walls of caves with traditional survey techniques because of their extension and morphological complexity. Virtualgeo, a company working in the fields of geomatics and software development to support the study and valorization of cultural and environmental heritage, has faced surveys in cave contexts several times. For example, in 2006 in Castellana Grotte (province of Bari, Italy) to assist with cave management, and in 2007 in Naica (northern Mexico) in the frame of the multidisciplinary research program organized by the Mexican company Speleoresearch & Films and the exploring team La Venta (Italy). In the Cave of Castellana, which is equipped with tourist facilities, Virtualgeo carried out the survey of the Grave room (100x40 m wide and 60 m high) with a “time of flight” laser scanner and acquired the spatial coordinates (and the RGB color values, thanks to the camera incorporated in the laser scanner) of more than 23 million points. In the giant gypsum caves of Naica, the company carried out the survey of the Cuevas de los Cristales and de las Espadas with a “phase shift” laser scanner and acquired more than 43 million points. In both cases Virtualgeo preferred laser scanning technique (acquisition rapidity, no-contact with the object to be surveyed, data completeness and precision, operational versatility) to traditional survey techniques in order to document the present conditions of the geometry of the caves and speleothems inside them by constructing high precision three-dimensional geometric databases with color information. Laser scanning can also be used as monitoring system, to check possible morphological changes appearing in time, and to carry out large surveys without disrupting work continuity.

The post-processing of the laser scanner data and the three-dimensional modeling of the morphology of the Caves of Castellana and Naica were performed with CloudCUBE, software for managing and three dimensional modeling point clouds developed by Virtualgeo on AutoCAD® platform. Using the same software it is also possible to extract any linear measure as well as compute areas and volumes from the digital model. The program allows one to automatically produce different graphic representations of the surveyed object (plans, sections, axonometric projections and cutaways). Thus it will be easy not only to study the present conditions of the caves (also by multitemporal analysis) but also to verify research hypotheses and evaluate possible projects.

Laser scanning technology is a practicable solution to document cave contexts in the most possible complete way, limiting risks connected with the insufficiency and/or inadequacy of data acquisition. It is suitable to rapidly survey large surfaces with a remarkable morphologic complexity otherwise impossible to be acquired with completeness.

### **Terrain Modeling and GIS Techniques for Cave Expeditions in China**

Mike Futrell

Cave explorers traverse the globe in search of ever more grand discoveries. The spectacular karst of China comes with many mapping challenges, including limited availability of good base maps. The space shuttle’s 2000 Shuttle Radar Topography Mission (SRTM) terrain model data was processed into base maps for these cave expeditions. Substitutes for standard topographic maps were created by contour extraction and automated sinkhole delineation. These layers serve as the base layers for the expedition GIS.

During the project locations of caves, springs, and geologic contacts populate the Geographic Information System (GIS). Daily updates of cave surveys added to the GIS allow team members to see how passages and hydrology relate to surface features.

By creating a karst GIS, intelligent choices for additional surface and in-cave prospecting as well as dye injection and monitoring points are well-supported. The SRTM data analysis approach has

been found to be indispensable and has directly led to significant discoveries.

### **Making a Digital Map of Wind Cave, Wind Cave National Park, South Dakota**

Rodney D. Horrocks and Daniel C. Austin

Completing a digital color map of the 209 km long Wind Cave was the culmination of a ten-year cartographic project. To our knowledge, this is the longest and most complex cave in the world that has been drawn as a single large-scale colorized digital map. Color was used to show multiple three dimensional levels on a two-dimensional surface. This process began in 1999, when a digital template for a Wind Cave quadrangle was created in Adobe Illustrator® and printed on Mylar at a scale of 6.09 m/cm. In plan view, each quadrangle covers 457.2 m by 304.8 m of the cave. Each of the 17 quadrangles was then divided into three layers: the upper, middle, and lower layers. Each quadrangle contains an index location map, a legend, and a cartographic history of that quad. Once all of the backlog cave surveys (72 km of survey data) had been drawn by pencil, and added to the 38 new Mylar quadrangle maps, these maps were scanned as single JPEG images. A master quadrangle template was then created in Adobe Illustrator® that was divided into an upper, middle, and lower layer. Each layer was further subdivided into individual cartographic elements (walls, ceiling heights, place names, etc.). Individual scans were then placed into their own layer and turned to 50% transparency, where they were used to trace or place each cartographic element onto its assigned layer. Finally, each of the three major layers was assigned a color (reddish brown for lower, tan for middle, and light green for the upper layer). Once all three layers were completed, all layers were made visible and the interior detail and text were adjusted so that most elements were not covered by an overlying passage. When the 17 master quadrangles were completed, each master quad was stitched to the adjoining quad beginning in the southwest corner of the cave. This resulted in a single 3 x 3.6 m digital colorized map of Wind Cave that can now be used for displays, management, or research.

### **The Sierra Negra in a PDA : Expedition-wide Electronic Cave Surveying**

Luc Le Blanc

In 2007, Mexpé, the Société Québécoise de Spéléologie's annual expedition to Mexico's Sierra Negra, celebrated the project's 20th anniversary with exploration results beyond expectations: over 10 km of new passages were discovered and mapped in less than a month. This feat also consecrated the definitive adoption of the Auriga cave survey freeware by the exploration teams for the underground input of survey data. Running on almost any PalmOS PDA, Auriga has since become part of our survey toolbox with the help of classic pocket-sized binders now fitted with a waterproof write-through pouch. The display features provided by the software help in avoiding survey blunders, locating the cause of closure errors, and sketching walls or passage features to scale. With all previous survey data of neighboring caves readily available in the PDA while surveying a new cave or passage, surveyors can see in real time their progress in relation to the rest of the known underground terrain and often anticipate connections. This data availability of the 6000+ survey shots composing the 40+ known caves of the Mexpé area becomes extremely convenient when searching for an old permanent station to connect with a newly discovered passage. Auriga is undergoing a rapid evolution, and the Mexpé test case presents some challenging survey situations that have helped bring about several field-use features like full GPS support, tools for resolving conflicting station names between teams or fixing input errors in bulk, and improved data handling capabilities (IR beaming, memory card securing, and export/merge of cave subsets). Carrying a computer in the cave even inspired features unrelated to surveying, such as a pit sounder where Auriga uses the PDA as a stopwatch to achieve quasi-metric depth precision by timing the fall of a rock. In 2009, the survey process will go electronic all the way, thanks to Bluetooth-connected measuring devices and the on-screen sketching of cave walls and features. Currently in use in several countries, Auriga is freeware, available online in three languages (French, English and Spanish), and comes with a comprehensive user manual, online help, and extensive support ([www.speleo.qc.ca/Auriga](http://www.speleo.qc.ca/Auriga)).

**2010 NSS CONVENTION ABSTRACTS**  
*(Essex Junction, Vermont)*

**Showing Three Dimensional Boneyard  
Mazes on a Two Dimensional Cave Map**

Rodney D. Horrocks

Cave cartographers have traditionally shied away from drawing multi-layered boneyard mazes on their cave maps; or they have only shown the main layers of those mazes. There are two methods that are effective in representing a boneyard maze. Both of these techniques allow the cartographer to draft every passage surveyed while including all of the interior passage detail. The first technique requires the use of color while the second only uses black and white. In the first technique, color is used in conjunction with transparencies. Each layer receives a unique color and is made partially transparent so the underlying layers can also be seen. The second technique involves using offset boxes. Depending of the numbers of layers, each offset box receives a unique label, such as "Upper, upper middle, middle, lower middle, or lower layer". A grayscale image of the upper middle layer is placed in the upper layer offset box underneath of the upper the passages layer. The connection points between these layers are then labeled. This is repeated until the lowest layer is drawn. Multiple examples of each of these techniques will be shown in this PowerPoint presentation. The use of color and the pros and cons of each technique will be discussed.

**Grotto Cartography Classes: Hints and  
Tips**

Howard Kalnitz

Interested in getting your grotto to produce more maps? Want to get more people involved in the mapping and cartography of projects? Sometimes you have to teach them how!

During this session we will go over a cartography class organized by the Greater Cincinnati Grotto. I will share lesson plans, exercises and PowerPoint resources, and talk about the philosophy and techniques of teaching cartography in a grotto setting. All interested parties are welcomed to attend and interact!

**2011 NSS CONVENTION ABSTRACTS**  
*(Glenwood Springs, Colorado)*

**Terrestrial LIDAR Scanning in Mammoth  
Cave National Park**

Aaron Addison

Early in 2010 a tripod mounted LIDAR unit was used to document over four kilometers of the Historic tour trail within Mammoth Cave. Over 120 stations were collected for a total data cloud of almost 20 million points. Data were used to create a high resolution 3D model of the cave passage. The model was used as a part of animation incorporated into interpretive exhibits at the new park visitor center.

Additionally, techniques developed during this project are being used for educational purposes, documentation, and resource management.

**Ledge Symboly in Profile Views**

Dwight Livingston

Plan views of cave maps typically include floor and ceiling ledge symbols, and cavers have long used them to comprehend and navigate important features such as drops, pits, traverses, and limits of a low ceiling.

Profile views, however, lack a corresponding ledge symbology, and cavers miss seeing equally important features such as side passages, windows, corners, traverses, and limits of a slot. This lack became apparent early in the mapping of Shoveleater, a five-mile cave in West Virginia so vertically complex that a clear representation of features in profile was especially desirable.

Various graphic devices were considered to show ledges, and one system was selected for its familiarity, consistency, and ease of recognition in a reduced print size. The Shoveleater Cave map now includes this symbology, alongside other novel graphic techniques, to render offset layers, link routes through multiple profiles, and create segmented projected profiles.

Many cavers find these new ledge symbols useful and natural to read, yet others find their similarity to plan view ledge symbols a hindrance to interpretation. The author contends that plan and

profile systems can be understood independently, and in that way can be interpreted easily by all. To encourage this approach, the Shoveleater map includes a separate plan key and profile key for some map symbols. This profile view ledge symbology is a valuable tool for cave cartography and should be added to the NSS symbol standard.

### **Regional Cave Survey and Urban Development: Karst Surveys For Public Consumption in Quintana Roo Mexico**

Simon Richards and James G. Coke IV

Cave exploration and survey in northeastern Quintana Roo reveals an increasingly complex network of dry and underwater caves. Over 920 kilometers of underwater passage is documented within a developing coastal region that is earmarked for municipal and touristic growth. Urban and tourist centers rely on complex relationships between modern infrastructure elements for growth and essential needs. As local communities and transportation networks grow, encounters with cave voids are inevitable. This creates a problematic arena for speleological survey groups. Government and non-governmental agencies invite local speleological survey groups to share geo-referenced survey data or map products for regional planning. Landowners may suffer uninvited scrutiny when precise cave entrances and passage locations are shared with these agencies. Sensitive survey data may wander to other government or private corporate concerns.

We propose an alternative method when sharing geo-referenced karst survey data through cave survey areas. Raw survey data is processed by modern software. A user-defined buffer is added to the elementary line plot, while passage and entrance references are removed. The buffer plot creates a boundary bubble which is exported to a Google Earth data file. Surveyors control sensitive data while allowing the public to review local cave areas.

## **2012 NSS CONVENTION ABSTRACTS (Lewisburg, West Virginia)**

### **Wide-area Cave Cartography**

Peter Sprouse

A regional approach is being used to create caves maps by multiple cartographers on a project in Quintana Roo. Line plots are exported from Walls to create a round-trip capable Adobe Illustrator file that can evolve with future added loops, connections, blunder corrections, and revised GPS fixes. Multiple AI maps can then be round-tripped into one map as caves join. Issues relating to quadrangle formatting and matching up borders beyond the maximum AI artboard size will be discussed. The AI template used by multiple cartographers includes standard line widths, drop-in symbols, and utilizing brushes to automate ceiling drop, floor drop, and flowstone lines.

### **Electronic Compass / Clinometers – Can we trust them? Lessons from 3 years of Disto X use**

Lynn W. Brucker

Electronic compass / clinometers for cave surveying offers many advantages over the traditional instruments, including no need to have your head behind the instrument, steep angles as easy to shoot as level shots, easier to use in tight passages, less operator error in reading results, easier to train new instrument people on operation and less time to become proficient. A major advantage is the data retained in the instrument can be downloaded to check the numbers written in the book after the survey trip. However, electronic compasses require calibration, which takes some time and the calibration will deteriorate with time. Lessons learned from three years of using multiple Disto X electronic compass / clinometers are discussed, including calibration challenges and hints, how long will a calibration last, and how can we know the instrument is working properly. Lessons learned from survey experience on setting stations, using targets, odd errors, and catching blunders is covered. The conclusion is that with careful attention to important details, the Disto X provides accurate data and significantly increases a team's ability to survey tight and awkward passages.

## **Sketching passage walls and features on a PDA screen – The Auriga experience**

Luc Le Blanc

Up to last December, Auriga, like the majority of cave survey software, only handled the numeric part of the survey data gathered underground. Sketches had to be drawn around transposed survey shots on a paper sheet next to the PDA running Auriga. Once scanned, these sketches could be opened in a drawing software (Illustrator, AutoCAD, Inkscape, etc.) and superimposed on the line plot exported from Auriga or some PC cave survey software like Compass. Since version 2.0 of Auriga, both the numeric data and sketches can be input by the PDA and exported simultaneously to the drawing software as a SVG or DXF file.

This presentation will explain the underlying principles of on-screen sketching in the Auriga freeware (shot-related sketching, self-adjusting curves, polylines vs polygons). All aspects of the sketching interface will be covered in a live demo, including the various sketch elements, conformance to stylus trace, curve-editing, layering, grouping and SVG/DXF export. Tips will be provided on how to proceed faster than with paper and yet obtain a raw sketch of passage walls and features that is easier to understand than its paper counterpart thanks to the use of colors and layers. A glimpse of upcoming features will be given.

On-screen sketching is only slowly picking up with Auriga users, even with those who had previously asked for it, this new feature obviously representing a paradigm change to classic surveyors. Nonetheless, everyone agrees the implementation is beyond their expectations in terms of simplicity and capability; those who adopt it enjoy its speed and convenience and would never want to go back.

## **Update on Beta Testing the DXT Disto X**

Lynn W Brucker

The Leica Disto D210XT is the dream Disto for cave surveyors. This new rugged, waterproof laser rangefinder is the perfect instrument for cave surveyors – so it was the logical choice for the platform for a new Disto X. The instrument's interior space is quite restricted in size for a parasite board for the compass / inclinometer and bluetooth functions, but Beat Heeb, the designer of the

original A3 based Disto X board, managed to do it. All looked promising until the testing what was expected to be the final prototype board. The new Disto X2 calibrated easily but the calibration deteriorated rapidly. The reason or reasons were unclear and various theories have been advanced and tested. This paper discusses testing of the prototype, various theories on cause of the poor results; including battery influence, case magnetic interference and temperature. As of mid-June 2012, the DXT Disto X is not ready for production or use.

Close Those Rocks (Before the Mud runs out)!

## **Hints and tips on adding colors to Maps in Illustrator**

Howard Kalnitz

Adding color to your maps is all the rage these days! The maps look great, the details pop, and the ability to understand complex passages goes up. However, it is sometimes difficult to get the effect you want.

This talk will look at adding color to maps from the beginning - focusing on Illustrator, we will look at how to close shapes to apply the color as the map is being drawn, and hints about how to make realistic details from hand sketches without covering up the sketch.

Please join us if you have any questions about adding color (or tips to share)

## **Fixing bad survey loops in Lechuguilla – There's an app for that!**

Luc Le Blanc

A related article published in the February 2012 issue of the NSS News described the loop-fixing process our team adopted during its week-long 2011 trip to the South area of Lechuguilla Cave. This presentation will offer a live demo of that process based on the extensive use of the Auriga cave survey freeware. After loading the Lechuguilla Cave survey data into a PDA running Auriga, survey loops were identified, rated by quality index, saved as individual subcaves and automatically analyzed for possible blunders. Once underground, survey shots in bad loops were re-measured and tie-ins were checked. The resulting data was then immediately entered in Auriga to re-compute the loop error and determine

whether the loop survey was now satisfactory. Updated survey shots that also belonged to other overlapping loops could then be propagated to these loops for reassessment. Using Auriga “live” in the cave allowed us to quickly know whether a bad loop had been fixed and by how much, and to decide which loop to fix next. Auriga thus made our loop-fixing mission more efficient and productive. Throughout the week, the availability of the entire survey data in a small and searchable form also proved extremely convenient to locate survey stations in this maze cave. At the end of the trip, all edited loops/subcaves were exported back into the main (South) cave to view overall results. From then, all survey shots modified during the week could be selectively exported in a cave file passed to the Park for updating their data repository.

## ***2013 NSS CONVENTION ABSTRACTS (Shippensburg, Pennsylvania)***

### **Two Centuries of Cartography at Mammoth Cave, a Whirlwind Tour**

Michael Sutton

Over a period of more than 200 years Mammoth Cave has had more time and effort spent on its cartographic depiction than any other cave. Mapping techniques have spanned the range from simple memory sketches to LIDAR. The history has been told many times; this presentation will hopefully illuminate some lesser-known aspects of that history and bring the story more or less up to date. Four hundred miles on and after all this effort, there is still no complete map of Mammoth Cave!

## ***2014 NSS CONVENTION ABSTRACTS (Huntsville, Alabama)***

### **Jitsy: A New Online Cave Database**

Jason Ballensky

Cave data are currently stored in a number of different formats and accessed using a variety of different tools and Web sites. Jitsy is a new Web site that offers a single location to store, access, and share cave data. Jitsy’s straightforward user interface makes it possible for anyone to easily create an

online cave database. Users may enter cave locations, plot locations on a map, upload photos, upload cave maps, and sort data.

Jitsy introduces the idea of cave collections. Caves are grouped together into collections, each of which has members who are allowed to access its cave information. This system lets users restrict access to sensitive cave data. In addition, the types of data displayed within each cave collection can be customized.

Jitsy is built on a social networking platform, which allows users to comment on caves and photos, track activity, and send messages. Future enhancements will allow users to upload trip reports and tag caves mentioned within.

### **Round-Tripping Multiple AI-Drafted Cave Maps Together Using Walls**

Peter Sprouse

When cave systems join, matching up existing drafted maps is problematic. The Walls cave mapping program solves this with the ability to round-trip multiple maps drafted in Adobe Illustrator into one, adjusting wall and floor details along with the survey baseline. This presentation will go through the process step by step of round-tripping two maps together.

### **New Survey Products by Swago Gear**

Scott McCrea

Swaygo Gear Shields are designed and engineered to add two layers of protection to the Suunto Tandem, KB14 compasses, and PM-5 clinometers. The die-cut, 30 mil lexan cover will help protect the fragile capsule from bumps and bangs. The clear, adhesive capsule circle will help prevent small cracks and contain fluid leaks, and the Swaygo Sight Lights, glow-in-the-dark instrument illumination, come preattached. Protects and illuminates. Swaygo Gear Lanyards increase efficiency while reading instruments. This amazing, completely nonmetallic, breakaway lanyard includes a small buckle that allows an instrument to be detached when sharing or stowing.



## Introducing Breakout: A Next Generation Cave Survey Visualizer

Andy Edwards

Large and complicated cave systems can be difficult to understand, especially for newcomers to a project. It can be much, easier than existing maps and cave survey viewers make it. My new program, Breakout, makes it easier to navigate between specific areas of large systems and perceive 3D relationships clearly. In addition, it can visualize spatial and temporal trends across an entire system that can guide decisions for future exploration.

## Alabama Cave Survey Online Database

Angela Morgan, Will Urbanski, and Andy Zellner

The Alabama Cave Survey (ACS) database went online in 2010, as [alabamacavesurvey.org](http://alabamacavesurvey.org), to provide members a portal to securely search and view the ACS-maintained cave data, narratives, and maps. The website also allows members to update their membership data as well as contribute cave information via a members-only wiki. The presentation will consist of an overview and demonstration of the website functionality along with technical information about its implementation.

## 2015 NSS CONVENTION ABSTRACTS (Waynesville, Missouri)

### Thomas Jefferson and America's First Cave Map

by Bert Ashbrook

Thomas Jefferson, author of the Declaration of Independence and third President of the United States, was also a cave owner (Natural Bridge and Saltpeter Cave), a speleo-paleontologist (*Megalonyx jeffersonii*), the editor of the nation's first cave survey (describing five Virginia caves), and America's first cave cartographer. In 1785, Jefferson published a map of Madison's Cave, Augusta County, Virginia, in his famous treatise, *Notes on the State of Virginia*.

Jefferson surveyed the cave on October 18, 1783, probably accompanied by his slave James Hemings and his 11-year old daughter Patsy. Strangely, he measured both distance and elevation, but not

azimuth. Jefferson's completed "Eye-draught" is instantly recognizable as a plan view of a cave. It includes floor slope symbols and a scale, but some of the passages are mis-oriented, indicating Jefferson's lack of a compass.

Why would the son of one of Virginia's most famous colonial surveyors have conducted such a survey? In a draft of his *Notes*, Jefferson described an earlier trip to the cave and the exploration of its waters by canoe, speculating whether they were connected to the branch of the Shenandoah River that still flows beneath the cave entrance. A draft of Jefferson's map—possibly his in-cave notes—not only includes additional detail like room names, but also a zero datum, floor elevations, and inclination measurements—none of which was included in his published map. This evidence indicates that Jefferson's reason for surveying Madison's Cave was to establish the elevation of its waters relative to the nearby river.

## Using a Tablet Computer with a DistoX for Paperless Cave Surveying – Some Technical Details

Brian Pease

The use of a DistoX compass-clino-distance device connected by Bluetooth to a small touch-screen computer allows sketching directly over the survey lines and cross sections while in the cave, potentially producing a working map in real time, particularly for a small cave. Beat Heeb produced the original DistoX modification board, based on a (now obsolete) Disto A3 laser rangefinder and paired it via a Bluetooth radio link with a color-screen Windows PDA running his PocketTopo survey and sketching software. More recently he produced a board to modify the current production waterproof/shockproof Disto E7400X creating the DistoX2. PocketTopo will also run on a full-size computer running Windows XP, 7, or 8 with Net Framework installed. It will also run in a Windows Mobile 5 emulator. With inexpensive tablet computers now available, it made sense to replace the PDA to obtain a larger screen and other features. I chose a Dell Dimension 10 with a 10" diagonal screen, but would have gone with 8" if one was available at the time that met all of my specs. With the Wacom active pen feature, one can draw on the screen while resting one's hand on the glass. Sketching through a waterproof case is also no

problem for the active pen. Both are problems with the PDA. The active pen does suffer from somewhat sluggish response and imperfect screen alignment.

### **Fast and Low Cost 3D Modeling of Caves via Consumer Camera.**

Cliff Gill

This presentation will report a method to create quantitative georeferenced 3D models of complete cave systems, including complex passages, large rooms, tight squeezes, and wet passage, using low cost consumer cameras easily transported in the cave environment. The technique can be done relatively quickly, substantially faster than traditional cave sketching, and results not only in a lidar like 3D model, but one with photographic textured surfaces ideal for scientific documentation or aesthetic appreciation. The method utilizes new photogrammetric software capable of processing ultra wide angle camera images. Non-georeferenced 3D cave models can be produced solely via photography. Georeferenced and scaled 3D models can be produced via the addition of conventional cave survey methods using distance, azimuth, and inclination measurements of photo identifiable survey stations. Enabling software for basic 3D model generation is cost effective at under \$200, and georeferenced results can be obtained for a similar price via subscription licensing.

### **Big Bat Cave LiDAR Project**

Ken Bailey and Ben Shinabery

Since our first ancestors began marking routes in caves with primitive tools or painting images with cinder, ash, and paint, man has been mapping caves. Some of the oldest traces of human history have been preserved by the constant climates underground. Through the collaboration between The Kentucky Karst Conservancy (KKC) and Qk4, Inc., the Big Bat Cave LiDAR project hopes to collect, map and preserve the fifty-sixth longest cave in the world. Instead of the cave preserving our history, it is our primary goal to digitally archive the cave to know better how to preserve its history.

Cave mapping worldwide generally is collected by hand with compass and measuring tape. While new handheld electronic distance meters are being used

in cave mapping they are based on the compass and tape survey methods collecting one data point at a time. Referencing those data points can be tedious and provide only a small subsample of the cave footprint. Cave mapping using LiDAR scanning enhances this process by collecting millions of data points while referencing them horizontally and vertically in 3D space.

LiDAR stands for Light Detection And Ranging. This LiDAR 3D scanning technology analyzes real world environments to collect data in a point cloud. Software is used to convert the data and construct digital 3D models of the existing features. For over a year, the KKC has been mapping Big Bat Cave in Breckenridge County, Kentucky with LiDAR data collection. We continue to develop our process in collecting and analyzing the geospatial data and gaining valuable experience below the surface.

The Kentucky Karst Conservancy (KKC) owns the land rights for the Mushroom Entrance to Big Bat Cave. The KKC maintains access to the Natural Entrance through a good working relationship with the landowner. Qk4, Inc. has provided the LiDAR technology and has created the digital subsurface mapping. One of the project goals is to expose students to new innovative ways of exploring the world around them. The KKC continues to offer an open invitation to students and staff at the University of Louisville Geography Department. Many have attended mapping trips. Students from Jefferson Community College and Southern Polytechnic State University in Georgia have also worked on the project. We encourage these students to reference this experience on the resumes. Any student that participates has full access to the data set. With help from local high school geography students, the KKC has plans of 3D printing portions of the digital cave model. To this point, the project has been self-funded and all personal cave equipment has been purchased, borrowed, or handmade by the participants.

The research possibilities in Cave LiDAR mapping are just beginning to be explored. Caves have been a preserved record of our past history and climate conditions. This LiDAR data set may shed insights into these paleo-climates and help the KKC preserve the story of Big Bat Cave.

## **Cartography challenges in surveying large multi-entrance cave systems**

Peter Bosted

Mapping long, complicated cave systems with many entrances presents some interesting challenges, especially when the host rock is iron-rich. Three case studies of volcanic caves on the Big Island, Hawaii, will be considered. In one area, a local cinder cone has caused a significant shift of magnetic north. In another area, GPS readings seem to be unreliable, possibly due to the proximity of an army base. In all three cave systems, magnetic north can be distorted by up to 40 degrees, especially near large tumbled boulders. I will discuss some of the techniques that have been developed to overcome these challenges.

## ***2016 NSS CONVENTION ABSTRACTS (Ely, Nevada)***

### **Leave Nothing but Footprints, kill Nothing but Time, Make... Photo-realistic 3D Computer Models**

John R. "Jack" Wood, Robyn Henderik, Benjamin Tobin, Chad Hults, and Blase Lasala

Photogrammetry uses multi-image photography to extract 3-dimensional (3D) information to map the surface of an object. The science of photogrammetry is nearly as old as the camera, yet only recently, through advances in camera technology, software, and computing power, has this technique become more common within the physical sciences. Photogrammetry is accessible to the average caver, yet is not widely utilized, even by researchers interested in caves. Cavers are the vanguard of speleology, with notable advances in the fields of geology, paleontology and biology initiated through their discoveries, and which were likely documented through photography. Cave photography has also benefited from increasingly sensitive and high-quality photographic sensors, improved compact optics and progressively smaller and robust housings. We present ideas and methods to show-case how cavers, using freeware and point-and-shoot cameras, can take advantage of photogrammetry to generate photo-realistic 3D representations. These data are useful for documentation of cave resources, especially for

locations not easily reached or on specimens that are impractical to recover. Scaling added to images can also create quantitative data, valuable to researchers, especially geoscientists, or those already engaged with resource photo-monitoring. Broader adaptation of photogrammetric technology by the caving community will further foster the inherent citizen-science aspect of cave exploration and enhance our understanding of caves and the resources contained within.

### **Electronics for Better Cave Surveys**

Bob Buecher

Cheap and sophisticated electronic devices are revolutionizing the way we survey caves. I will demonstrate a small LIDAR system that I have been using to survey caves for the last two years. It can be constructed for less than \$350. While much simpler than commercial LIDAR units it does not cost \$100,000 and weighs less than 3 pounds. It can perform a complete 360 degree spherical scan in less than 5 minutes. Range of the scanner in caves is up to 40 meters with centimeter accuracy. Data is recorded on an SD card. A separate computer is needed to display the point cloud generated by the scanner.

I will also show how I have constructed and used small micro-barometers / altimeters to determine the elevations in a large cave. In Fort Stanton Cave, the Snowy River passage extends upstream for over 10 miles and the gradient is less than 0.2%. Normal cave survey methods were not able to measure this flat slope, or even confirm that water was indeed flowing downhill. By using up to four micro-barometers the slope and elevations were measured to an accuracy of 2 feet. The accuracy of the barometric elevations was also independently confirmed by a cave radio location and depth measurement.

### **Creating a Virtual Model of Timpanogos Cave National Monument**

Blase Lasala

In the fall and winter of 2015, the majority of passages that comprise Timpanogos Cave National Monument were digitized with a terrestrial laser scanner. Over 30 formations were also digitized using photogrammetric techniques. While the

technology is limited, with price and durability being large factors, what can be achieved with modern hardware might surprise you. This informal talk will be cover how reality capture devices differ from traditional cave survey, the techniques used when working with expensive electronics underground and the unique challenges associated with capturing a highly decorated and fragile cave system. This talk will also be showcasing some examples of what this data can be used for, illustrated with proof of concepts created from the Timpanogos Cave master point cloud.

-- end of abstracts --