Survey Instruments: Digital or manual? A field comparison of relative accuracy and practicality of usage.

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Measuring Azimuth & Inclination

Clinomaster &
Sight Master

Suunto Tandem

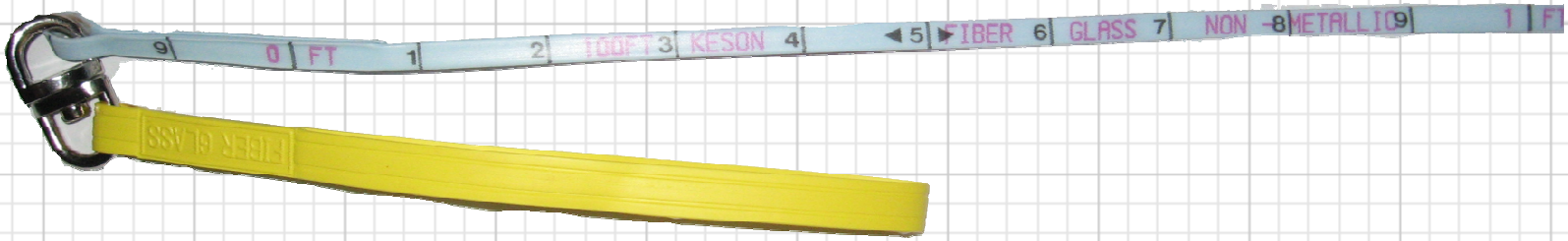
Shetland Attack Pony

TruPulse 360

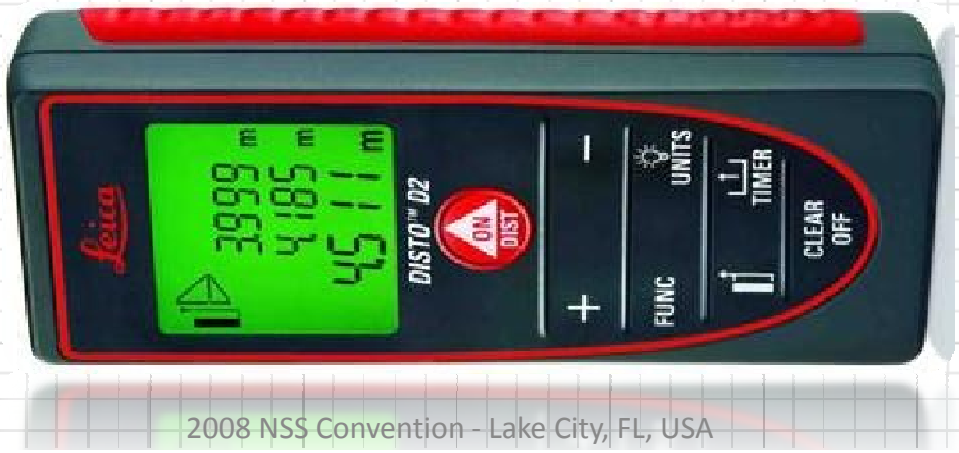
Impulse, measures inclination only

Measuring Distance

Survey Tapes Graduated in Tenths of Feet



Digital Laser Measurement Device



Survey Book

- Recording the data

Cave Future Is Now Page ϕ of ∞

Station	CAVE SURVEY			L	R	U	D	Notes
	Distance	Azimuth	Vertical Angle					
1	27.1	fs 140	fs +1	4	6	20	4	Station on boulder
2		bs 321	bs 0	19	20	8	3	
3	38.2	fs 138	fs -4					
		bs 319	bs +3	16	10	10	4	
4	19.5	fs 152	fs -6					
		bs 333	bs +6	10	8	6	2.5	Station near pool of H2O
5	8.7	fs 139	fs -2					
		bs 319	bs +3					
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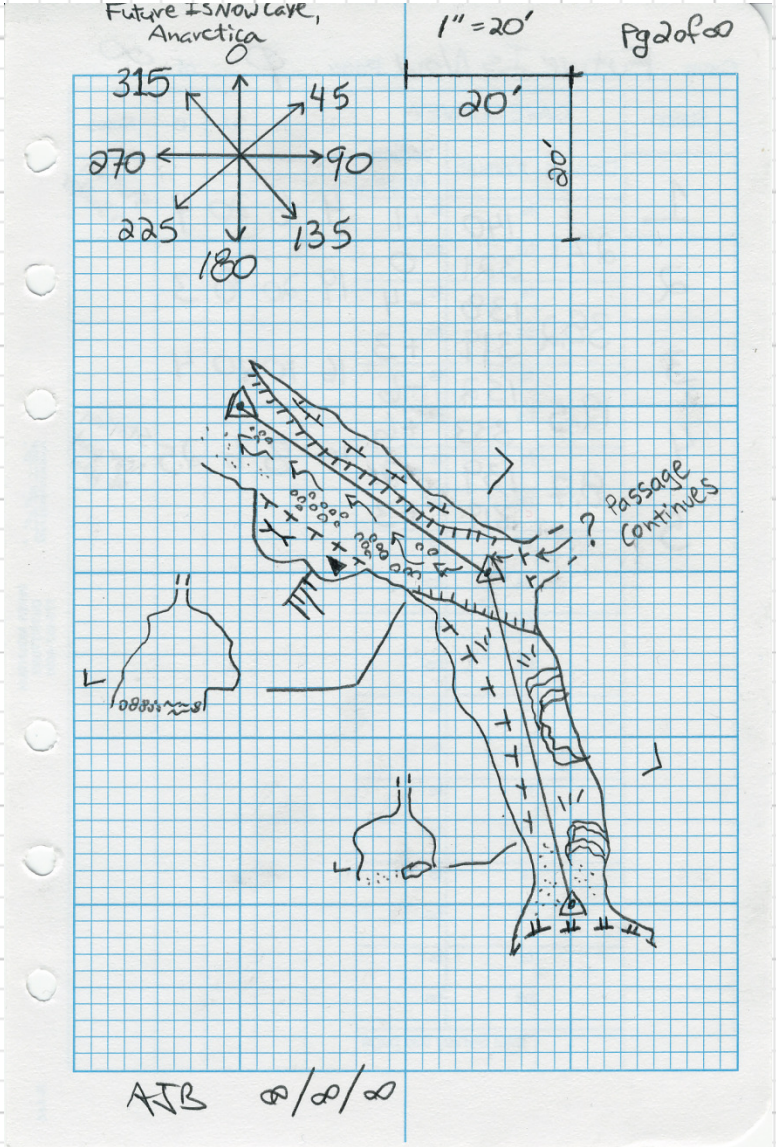


- Sketching the cave

Survey Computer

- Recording the data
- Crunching the data
- Sketching the cave

Why use digital survey tools?

- Reduce or eliminate blunders
- Increase accuracy of survey data
- Increase repeatability of data
- Make surveying process easier
- Make surveying process faster

Common blunders during the survey trip

Compiled by Bob Hoke and Pat Kambesis Compass & Tape(V17n4i60p17)

- Reading wrong side of survey tape for tapes with different graduations on either side
- Reading wrong direction in compass, called “Decade Inversion”
- Magnetic effects
- Communication problems
- Recording errors

Common blunders …

- Reading wrong side of survey tape for tapes with different graduations on either side
  - Disto readout set for feet in tenths
- Reading wrong direction in compass, called “Decade Inversion”
  - TruPulse or Attack Pony displays azimuth in degrees
- Magnetic effects
  - Got to minimize them no matter what device is used
- Communication problems
  - Be nice, be polite, be patient. ☺
- Recording errors
  - Can happen with/without digital devices
  - Using BlueTooth where data automatically uploaded to computer

Mark Passerby: “Suggested equipment for ICDS”

Source: Mark Passerby, InCaveDigitalSurvey.com, http://incavedigitalsurvey.com/board/YaBB.pl?num=1205624025

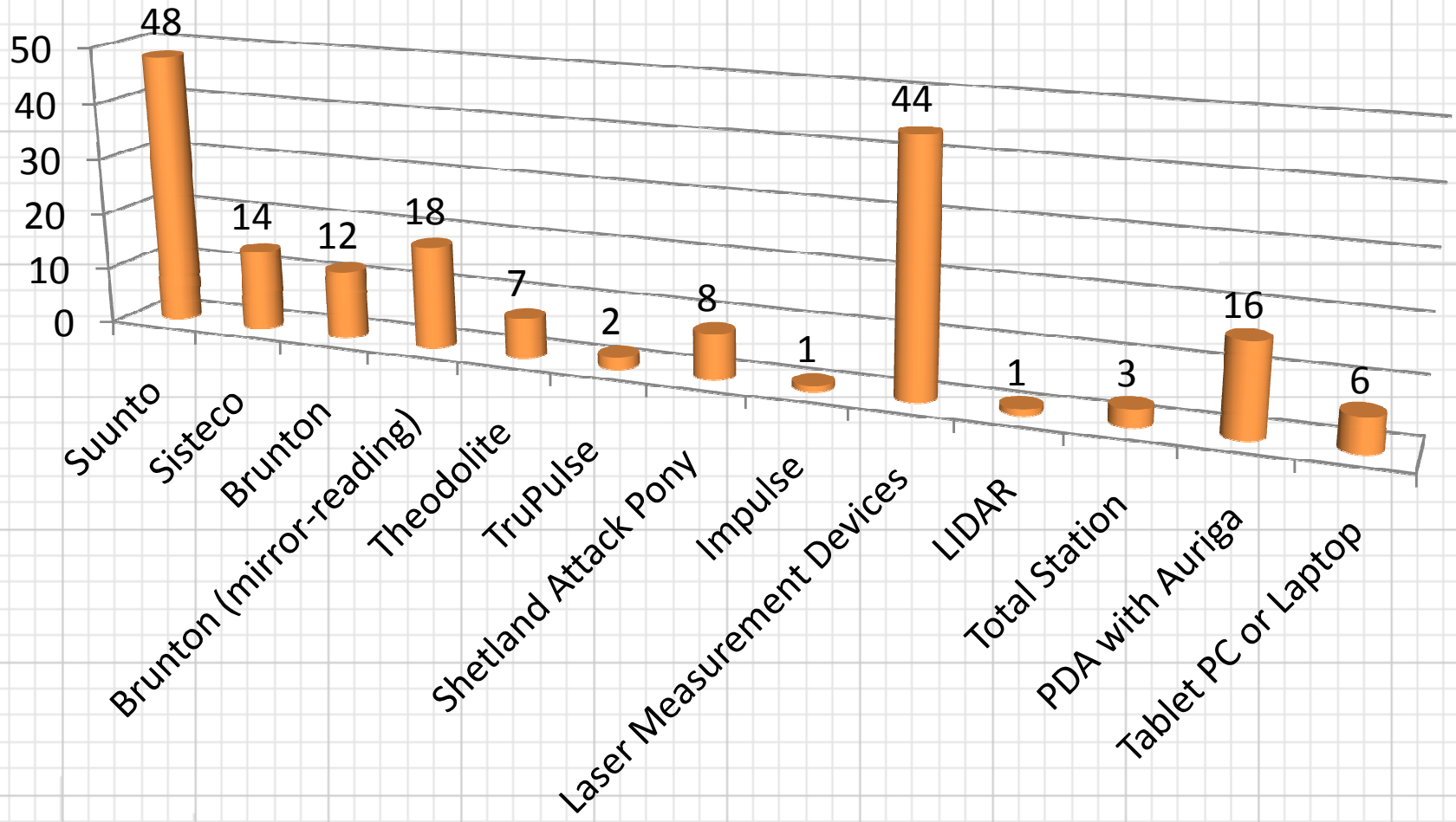
Some Background on In-Cave Digital Survey

- Mark Passerby (Caves.Com Magazine, 2003): "Perhaps nothing is changing faster in caving than the surveying process."
  - Reviewed Disto Laser Measure and concluded it was a very functional device. (Many surveyors use Distos and other laser measuring tools today.)
  - Reviewed CheckPoint Inclo-Matic concluding it was a very good tool. (Many devices are available today.)
  - Reviewed Bushnell digital compass with conclusion that, "…digital compasses aren't there yet."

Now… fast forward to 2008, Online Survey Results

- Online survey conducted from July 18 – August 2008
- A total of 52 respondents
- Most use Suuntos
- Most use Disto (laser range finders)
- Many believe digital tools are ready for in-cave use
- Excepting laser range finders, few actually use digital survey tools

Online Survey Results



Process for Using Digital Survey Tools Differs from that of Traditional Sighting Instruments

- Calibrate to known standard azimuths and inclinations
- Prepare the instrument for the cave environment
  - Waterproof, impact proof cases
  - Extra batteries
  - Targets
- Collect data according to proper use of instrument
  - Data collection is not necessarily like using Suuntos

Calibration: Suuntos?

- Traditional cave surveying instruments can be "corrected" (Andreatta, 2005).
  - The instruments, and their readers, do require checking for accuracy using known survey stations and possible adjustment by a correction factor
    - Goal is frontsight/backsight agreement of +/- 1 degree
    - Dasher (1995): "…probable that more error will creep into the survey from instruments' users inability to accurately shoot the instrument…"
    - Andreatta (2005): "Assuming no major blunders, the largest source of error is instrument error."

Calibration: Digital

- Digital instruments do require calibration
- TruPulse 360 calibration procedure takes ~1 minute and can be done anywhere, provided magnetic north is known within +/- 17 degrees (LaserTechnology, 2007)
- Shetland Attack Pony calibration procedure (Underwood, 2007) takes up to 2 hours or as little as 30 minutes, has been done in a cave (Brucker, 2008), must be done free from magnetic or EMF interference

TruPulse Calibration Procedure

- Turn on instrument
- Cycle menu to calibration
- Take 8 shots according to calibration process
- Wait for “PASS” or “FAIL”
- If PASS, use instrument
- Takes ~ 1 minute for a practiced user
  - ~3 minutes for an unpracticed user

Pony Calibration Procedure

- From the manufacturer (Underwood, 2007)
  - Set Pony to “Raw” data collection
  - Run the calibration course with Suuntos or other instruments to determine “Truth” shots
  - Collect data with Pony in four orientations

Pony at FROM station

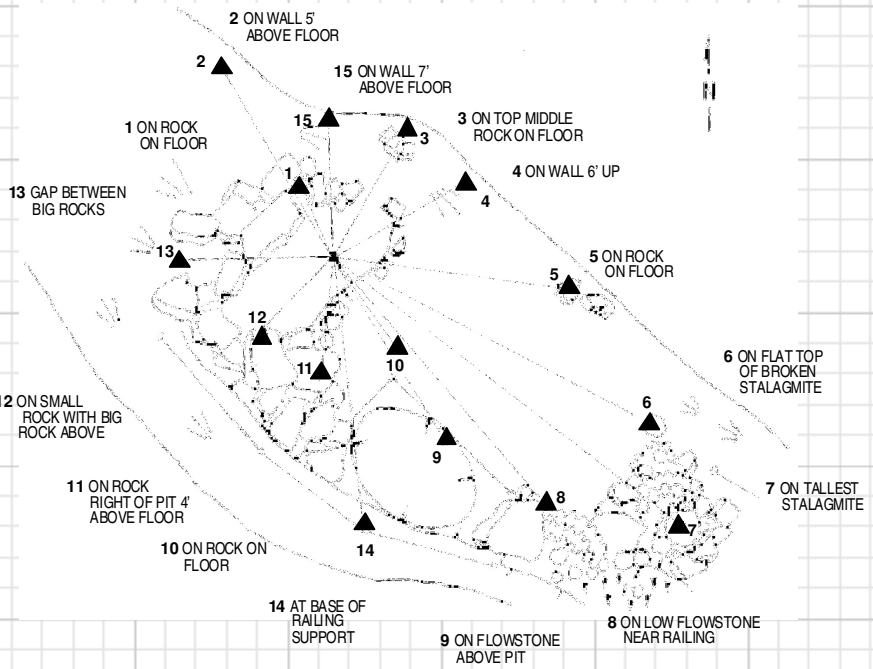
0 degrees orientation

90

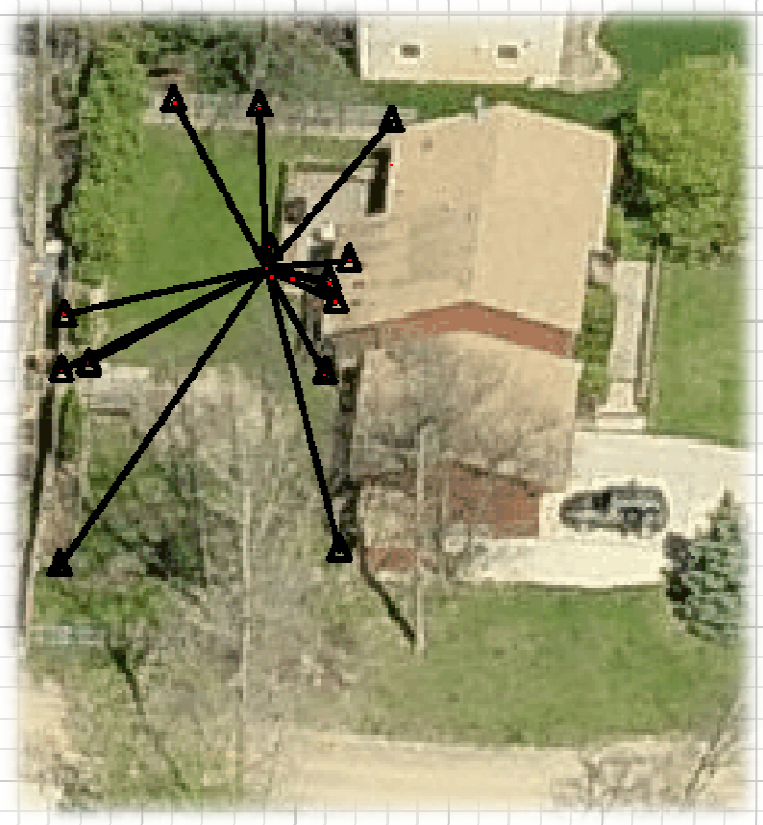
180

270

Calibration of Shetland Attack Pony



In-cave Pony Calibration Course in Great Onyx, Cave, KY. Lynn Brucker, 2008. Used with permission.



Backyard Pony Calibration Course in Lake Orion, MI. Aaron Bird & Rachel Bosch, 2008.

4 Pony Shots (Orientations) at each station.

Evaluating Effectiveness of Device after Calibration

- Goal: +/- 1 Degree (CRF Field Handbook; Andreatta, C&Tv17n1i57p20, 2005)
- Achieved in some tests at the Cave Research Foundation Frontsight/Backsight course at Hamilton Valley Fieldstation
- Achieved multiple times in backyard calibration course in Lake Orion

Frontsights and Backsights

CRF Hamilton Valley Fieldstation, 07/25/08

	Azimuth		Inclination	
	Frontsight	Backsight	Frontsight	Backsight
Pony	128	309	0	0
Suunto	129	308	0	0

Lake Orion, MI, 07/31/08

	Azimuth		Inclination	
	Frontsight	Backsight	Frontsight	Backsight
Pony	294	114	0	-1

Lake Orion, MI, 08/04/08

	Azimuth		Inclination	
	Frontsight	Backsight	Frontsight	Backsight
Pony	294	115	0	-1
Suunto	294	114	0	-1

Field Testing

- Dogwood Cave, KY
- Roppel Cave, KY
- Whigpistle Cave, KY (no shots taken, “survivability exam 1”)
- Martin Ridge Cave, KY (shots taken, “survivability exam 2”)
- Windy Slope Cave, WV (shots taken, “survivability exam 3”)
- Colossal Cave, KY

CRF Hamilton Valley Fieldstation, 06/15/2008

	Suunto		TruPulse		SAP		Azimuth > 1^0		Inclination > 1^0	
STA	AZI	INC	AZI	INC	AZI	INC	Suunto - TruPulse	Suunto - SAP	Suunto - TruPulse	Suunto - SAP
0 to 1	144	9.5	144	9.4	144	9				
0 to 2	126	1.5	126.3	1.6	126	1				
0 to 3	121	10	119.7	9.9	120	10	1.3			
0 to 4	73	19	72.6	19.1	73	19				
0 to 5	357	-6.5	356.7	-7.7	356	-7			1.2	
0 to 6	337.5	12.5	336.5	11.4	336	11		1.5	1.1	
0 to 7	301	6	300.2	5.9	300	6				
0 to 8	294	7.5	293.4	6.5	293	6				1.5
0 to 9	206.5	0	205.6	-0.9	206	0				
0 to 10	163	3	162.9	1.6	163	1			1.4	2
0 to 11	164	-9	162.8	-9.6	163	-9	1.2			
0 to 12	152.5	2	151	2.1	151	2	1.5	1.5		

38 < 1 degree, 10 > 1 degree, 0 > 2 degrees

Dogwood Cave, KY 06/16/2008

Instrument	AZI	INC
Suunto 1	321	-7
Suunto 2	324	-7
TruPulse 360 1	322.2	-6.5
TruPulse 360 2	322.2	-5.9
SAP 1	321	-7
SAP 2	321	-7

1 outlier? 2 > 1 degree, 0 > 2 degrees

Roppel Cave, KY 06/18/2008

	Frontsight		Backsight	
Instrument	AZI	INC	AZI	INC
Suunto 1	327.5	0	147.5	0
Suunto 2	327.5	0	151.5	-0.5
SAP 1 (A&R)	328	-1	152	0
SAP 2 (L&R)	327	-1	153	0

5 < 1 degree, 3 outliers? Probably not… something going on here.

Martin Ridge Cave, KY 07/26/2008

	Frontsight		Backsight	
Instrument	AZI	INC	AZI	INC
Suunto 1, AJB	41	+7	220	-7
Suunto 1, LAB	41	+7	221	-8
SAP, AJB	39	6	218	-8
SAP, LAB	39	6	218	-8

3 = 1 degree, 1 > 2 degrees

Windy Slope Cave, WV 08/02/2008
High-Angle Shots

Frontsight (SAP)		Backsight (Suuntos)	
AZI	INC	AZI	INC
125	-7	306.5	5
121	32	301	-31
117	41	297	-41
278	37	98	-36

3 < 1 degree, 1 = 1.5 degrees; 1 inclination = 2 degrees

Colossal Cave, Mammoth Cave, KY
08/02/08, no shots > 1 degree different

Frontsight		Backsight	
359	11	180	-11
306	11	127	-11
340	1	161	-1
25	0	204	0
357	0	177	0
14	7	194	-7
319	-12	139	11
158	-44	339	45
88	-5	267	4
105	0	284	0
70	-6	249	6
87	-80	267	80
176	-18	355	18
197	-20	17	19
152	-5	331	5
143	21	323	-21
215	3	35	-3
196	0	15	0
210	1	30	-1
174	0	354	-1

Greg Holbrook and Pony in Colossal Cave, KY
08/02/08

Average Difference in Azimuths^ and Inclinations*

- Dogwood Cave = 0.6 degrees^, excluding outlier; 1.2 degrees^, including
- Roppel Cave = 0.6 degrees^, excluding; 2.1^, including
- Martin Ridge Cave = 1.3 degrees^
- Windy Slope = 1 degree*
- Colossal Cave = 0.55 degree^, 0.25 degree*; loop closed in Colossal with gross error of 0.5 feet horizontal, 1.65 vertical

Survivability Exams…

- Whigpistle Cave, KY
  - Pony packed in Otterbox and Drybag, padded with Fleece pullover
  - Cave pack was completely immersed for hundreds of feet of cave passage
  - **Attack pony survived!**
- Martin Ridge Cave, KY
  - Pony packed in Otterbox and Drybag
  - Cave pack was beaten around like a normal pack is
  - **Attack pony survived!**
- Windy Slope Cave, WV
  - Pony packed in Otterbox and Drybag, padded with Fleece pullover
  - Cave pack was immersed, dragged, dropped, beaten up, and immersed again
  - **Attack pony survived!**

Useability

- TruPulse 360
  - Can be hand held, but mounting on a non-magnetic tripod is much, much better
- Pony
  - Designed to be used at arm's length. For some shots getting the laser to "settle" down is difficult. In this case, use a nonmagnetic "bean bag."
- Laser Range Finders
  - Extremely easy to use, reasonably rugged, already relatively widely used for LRUDs

Overall Assessment

Instrument	Accuracy	Precision (FSB)	Useability	Calibration Procedure	In-Cave Usage	Cost	Overall
TruPulse 360	Excellent	Excellent on "good stations"	Excellent	Excellent	Poor (Instrument is not "cave proof")	$1,600	Accurate and very easy to use, but too expensive, not cave proof
Suuntos	Excellent	Excellent on "good stations"	OK	Very good, actually is a "correction" procedure	Excellent	$200	Reliable, affordable, subject to blunders
Shetland Attack Pony	Excellent	Excellent on "good stations"	Very Good	Poor	Very Good	$500	Accurate, very easy to use, but calibration is difficult

Conclusions, Digital Devices for Cave Surveying

PROS	CONS
Easy to use	Costly
Very quick, reliable data collection	Requires calibration, usually in low light (nighttime, indoors, or in a cave)
Appear to be accurate within +/- 2 degrees (mostly w/in +/- 1 degree)	Not always cave proof, must be cared for while in cave

Potential Future Directions

- BlueTooth functionality for Shetland Attack Pony
- Tools like PDA w/ Auriga may be used to update line plot in nearly real time
  - Applications would be go beyond cave surveying, could include mine surveying, search and rescue, building collapse rescue, environmental/exposure tracking, etc.

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- Nikki Green - Cheat Canyon Cave Survey
- Charles Fox - Cave Research Foundation
- Greg Holbrook - Cave Research Foundation

References

- Andreatta, 2005. Compass and Tape, Vol. 17, No. 1, Issue 57, pg. 20.
- Dasher, George. 1995. Compass and Tape.
- Hoke, Bob and Kambesis, Pat. Common Blunders During the Survey Trip. Compass and Tape, Vol. 17, No. 4, Issue 60, pg 17.
- Passerby, Mark. InCaveDigitalSurvey.com http://incavedigitalsurvey.com/board/YaBB.pl?num=1205624025 (accessed July 2008).
- Passerby, Mark. 2003. Caves.Com The Magazine.
- Laser Technology. 2007. TruPulse 360 User Manual
- Brucker, Lynn. 2008. Underground Calibration of the Shetland Attack Pony. To be published in Compass and Tape.
- Addison, Aaron. 2008. To be published
- Underwood, Phil. 2007. Shetland Attack Pony User Manual.

Questions?