Terrestrial 3D Laser Scanning to Rebuild Son Doong Cave

Quang HOANG KIM, Binh NGUYEN THI THANH, Phong NGUYEN MINH, and Vu DANG NGUYEN, Vietnam

Key words: Cave, Son Doong, 3DLASERSCAN, Vietnam

SUMMARY

Son Doong cave (Hang Son Doong in Vietnamese) is The World Most Largest Cave (announced by cave founders and expert at Quang Binh province) was found in 1991 by a local forester named Ho Khanh. In 2009 an expert caving team from England together with local forester Ho Khanh made a trip to re-locate and get detail information to uncover the myth of "Mountain River Cave" (local meaningful the name of Son Doong cave). To get to Son Doong cave is absolutely not so easy, the way goes through jungle, river, rocky mountain and it took at least two days and one night in En Cave before approach to Son Doong Cave door.

In 2014 and 2015 a joining team from Vietnam Television - VTV and ANTHI VIETNAM Co., Ltd. made two trips to Son Doong cave to again measure and redraw the cave in 3D model and also redefine and calculate shape, dimensions, volume by mean of using cutting edge technologies such as 3D laser scanning, high accuracy laser rangefinder, software processing, high definition (HD) recorders for filming and documentation purposes.

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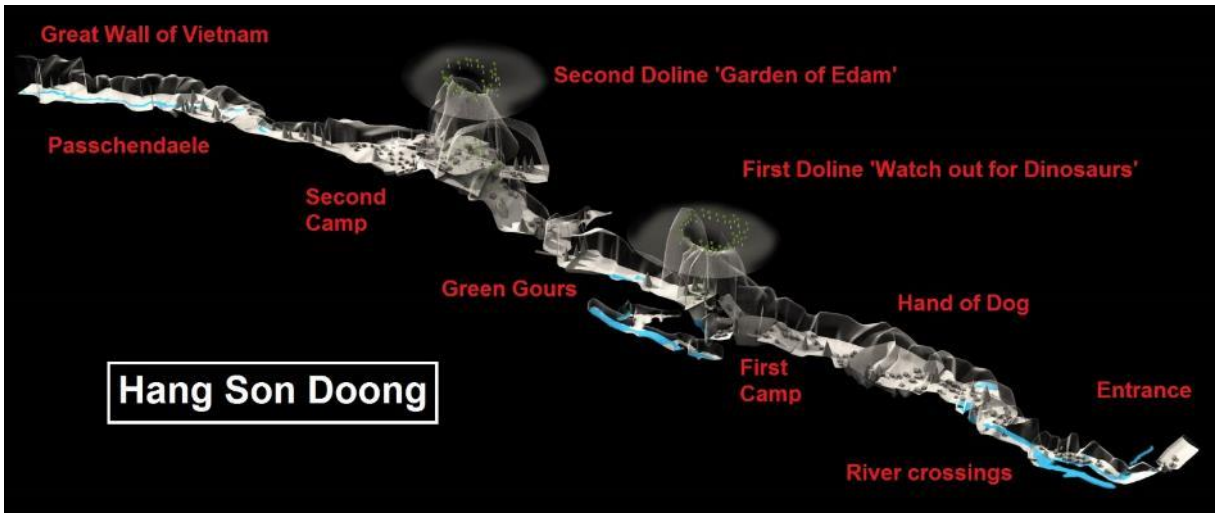
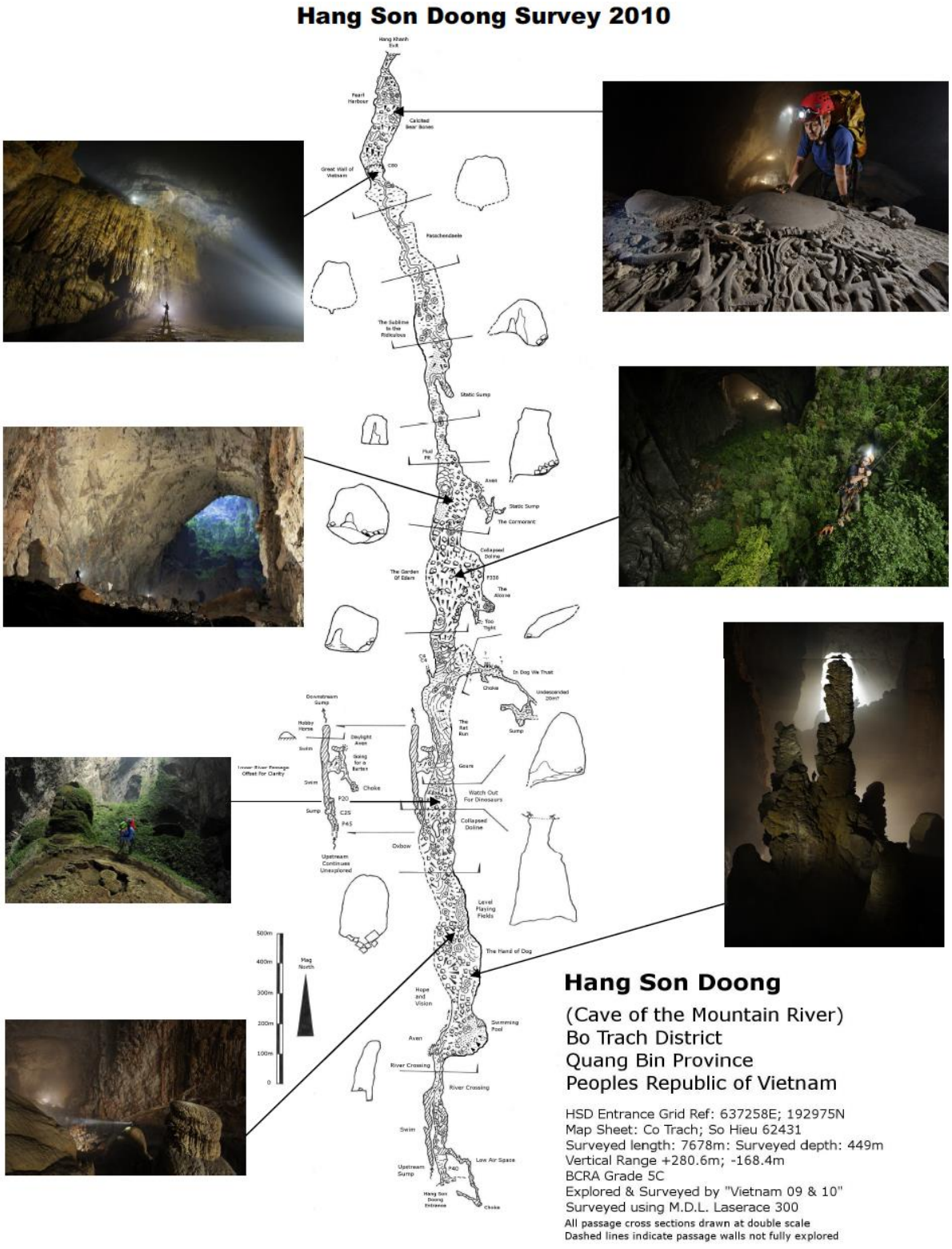
1. SON DOONG CAVE EXISTING INFORMATION

Son Doong cave located in Quang Binh province, Vietnam was recently discovered in 2009 by British cavers, led by Howard Limberts. Son Doong cave was created around 2-5 million years ago by river water eroding away the limestone underneath the mountain, limestones were weak, the ceiling collapsed creating huge skylights, passages and chambers.
Son Doong is one of the world's largest caves, with enormous chambers that can comfortably fit a 747 airplane or an entire New York City block full of 40-story buildings. (According to National Geographic).

The main Son Dong cave passage is the largest known cave passage in the world by volume 38.4×106 cubic metres. It is more than 5 kilometres long, 200 metres high and 150 metres wide. Its cross-section is believed to be twice that of the next largest passage, in Deer Cave, Malaysia. (According to Howard Limberts).





The cave runs for approximately 9 kilometres and is punctuated by 2 large dolines, which are areas where the ceiling of the cave has collapsed. The dolines allow sunlight to enter sections of the cave

which has resulted in the growth of trees as well as other vegetation. (According to Howard Limberts).

2. REQUIREMENTS

Early of 2014, Vietnam Television (VTV) under supporting of Japan Government started to promote for a new program called "VTV Special" and the story of Son Doong cave selected to be the first show to open VTV Special program.

Board management of VTV and the director of program already called for some local survey and design companies in Vietnam for discussion about the ability to get data for whole Son Doong cave system in detail as much as possible, unfortunately all of requirements from VTV Special program could not fulfill based on traditional survey methods proposed by local survey and design companies. The proposed solution from ANTHI Vietnam Co. Ltd. was reviewed at the last because at this time 3D laser scanning technics and almost of program personnel never seen the real system equipment and created deliverables and they were really concerned about the ability to supply data as their requirements. After a three months with many meeting and technical explanation, VTV Special program decided to select ANTHI as a joining partner for the Son Dong cave data and film project.

According to the awarded contract, ANTHI must supply and make for sure to complete data for Son Dong cave as below:

- Whole data of Son Doong cave must be collected by 3D laser scanners;
- Rebuild complete detail the shape of the cave in 3D models (from point cloud and solid);
- Extract vertical cross sections together with dimension for whole of the cave in every 50 meters of interval;
- Measure and supply dimension for 02 doline of the cave, the smallest and the largest sectors of the cave;
- Scan and rebuild "The Great Wall of Vietnam" inside the cave in detail;
- Calculate and supply information about the length of the cave;
- Calculate and supply information about the volume of the cave;
- Compare scanned aircraft and/or high rise building to rebuilt model of the cave at scale 1:1;
- Create video clips as requirement of director of picture for filming (from both 3D models point cloud and solid);
- Test 3D images and video clips for RED & BLUE glasses.

3. DATA COLLECTION

3.1 Equipment

The first trip to Son Doong cave made in September 2014, the team brought below equipment through front door of the cave. We worked in the cave for 8 days.

No.	Equipment Descriptions	Qty.	Note
1	Leica ScanStation C10 scanner (Full set)	1	Carbon Tripod
2	FARO FOCUS 3D S120 scanner (Full set)	1	Aluminum Tripod

3	Panasonic Toughbook CF-53 Computer	1	
4	Dell Dimension Mobi WorkStation	1	
5	FARO SCENE Software	1	
6	Gexcel JRC Tunnel & Mining Software	1	
7	Handheld Rangefinder LaserTech TruPulse 360R	2	
8	Drone (4 and 6 propellers)	3	DIY drones
9	Honda Power Generator	1	40 kg
10	Technician (person)	4	
11	Nikon 5D camera, GoPro and Sony camcorders	1 set	

The second trip was made in January 2015, the team brought below equipment through back door of the cave. We worked in the cave for 2 days.

No.	Equipment Descriptions	Qty.	Note
2	FARO FOCUS X330 scanner (Full set)	1	Aluminum Tripod
3	Panasonic Toughbook CF-53 Computer	1	
4	Dell Dimension Mobi WorkStation	1	
5	FARO SCENE Software	1	
6	Gexcel JRC Tunnel & Mining Software	1	
7	Handheld Rangefinder LaserTech TruPulse 360R	2	
8	Drone 4 propellers	1a`	DIY drones
9	Honda Power Generator	1	40 kg
10	Technician (person)	2	
11	Nikon 5D camera, GoPro and Sony camcorders	1 set	

3.2 Field data collection

August September is the starting time of rainy season in Quang Binh province, heavy rain previous days had swollen the rivers, making challenging river crossings to reach the cave entrance after traversing from En Cave through Phong Nha Ke Bang jungle to reach Son Dong cave entrance.
Two river crossing points right after we getting down nearly 80m behind entrance flooding required the team to swim against the current with the equipment tied onto an inner tube and log raft and each member must swim along strong rope anchoring to both side of river. After nearly 1,000 m crossed the rock collapsed field all teams touch the campsite and start to set up generators to light up the cave with a thousand watts daylights and strong headlamps in order to throw the light to all corners, walls and ceiling of the cave.

Every day in the cave, our team started to work from 8 a.m. until 10 p.m. because the plan already fixed for all parts of the program such as VTV, researchers and supporting team. Morning inside the cave quite cold and very misty, we must shortened distance between scan stations because mist can absorb the laser energy and so prevent long range measurements. In the first session, we scanned, downloaded and calculated maximum scan range with the cave's conditions for Leica ScanStation C10, FARO S120 and FARO X330, this process to make for sure data will be collected completely.
The differentiation of terrain and shape inside the cave did not allow to set distance for each scan station longer that 70 m. In total the team spent nine days and eight nights in the cave to collect data

with 150 scan station (for all of scanners). Two laser rangefinder LaserTech TruPulse 360R were used to check the distances between the scanner stations and this information will be used during registration process. Two doline of the cave were the hardest points for crossing and scanning, the doline named “Watch out for Dinosaurs” was the highest point of the cave the height measured more than 300 m. At the end of each day when all team be back to campsite, a day scanned data downloaded to computer and run registration to review and find missing parts as “hole” and scan to fix next day.

Heavy rain continued and water immersed about 400m of Mud Lake at the end of the cave and we could not reach to the final point of the cave called The Great Wall of Vietnam and this section was not presented in our database and models. According to local men, water depth in the Mud Lake at this time may up to 30m. The day that we got out of the cave was heavy rain and it were really difficult for all team to bring all equipment out.

Instead of get in the cave through front entrance as we did in the first trip 2014, in the second trip we made early of 2015 we took another way to reach back entrance, way was shorten but much difficult than the way to reach front entrance. Through this way we already scanned almost of The Great Wall of Vietnam, height of the wall more than 70m plus 30m under water and in the second time, we still unable to get to the Mud Lake because water level in the lake still very high.
Images below were taken by author Quang HOANG KIM for Son Doong cave trip.

Last check for all drones system and pick up cars for departure day

Honda generator and Leica ScanStation C10 heading to Son Doong cave

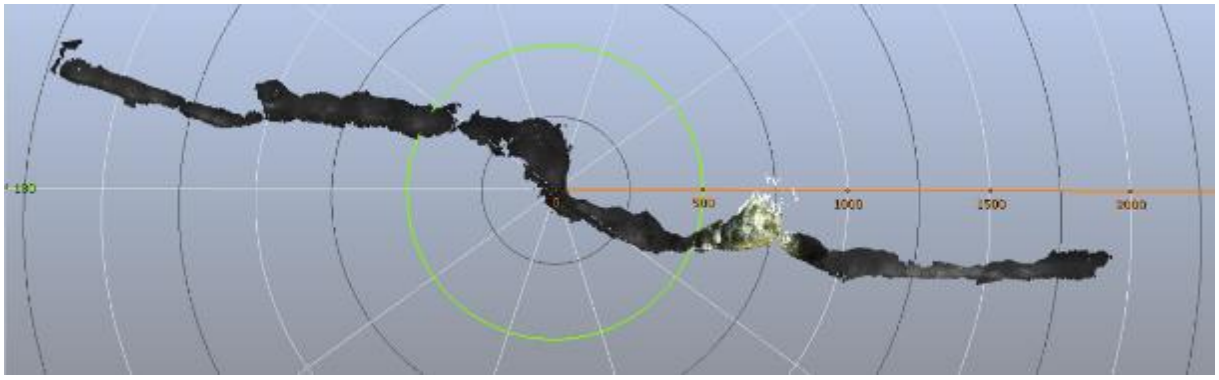
Along the track heading to Son Dong front entrance

Moving, scanning, data downloading inside Son Doong cave

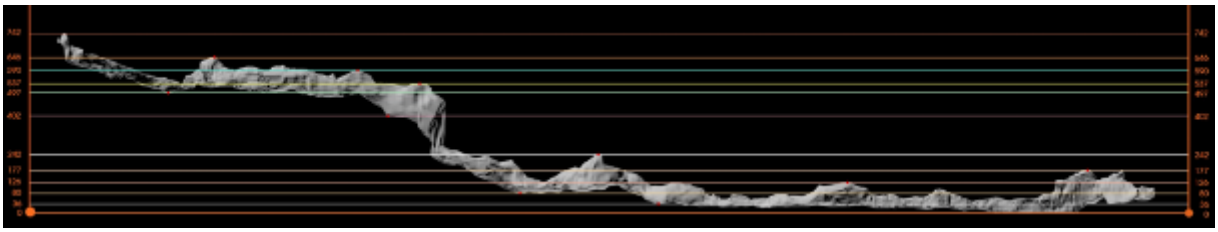
4. PROCESSING AND DELIVERABLES

Inside the cave, at the end of each day team already roughly registration almost of scan stations to check. In the office, beside special application software from Vietnam Television team, ANTHI team had to check again for completely registration, filtering scanned data and export data to Gexcel JRC, Autodesk and Bentley Pointools software to build different 3D models.

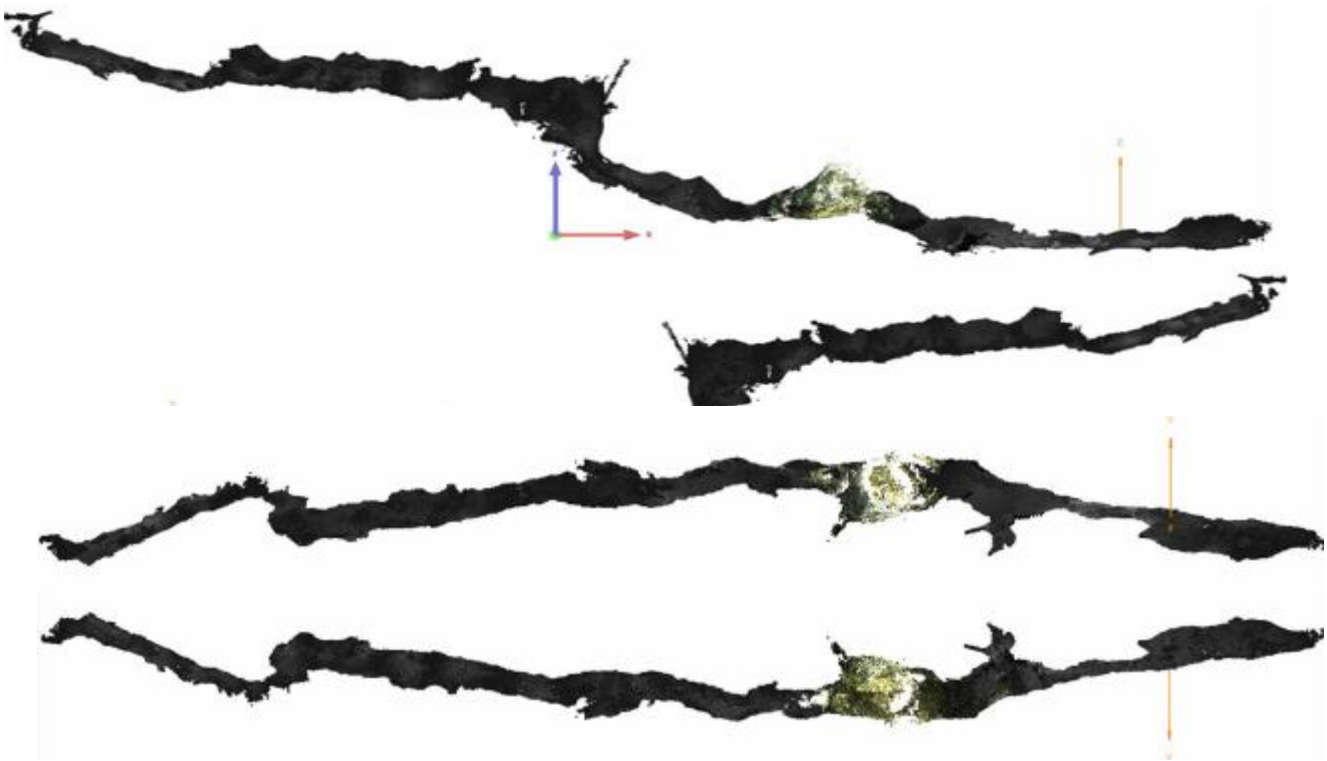
According to awarded contract from Vietnam Television, all of deliverables created by our team to fit their needs for filming. Other deliverables also created to serve for other purposes.



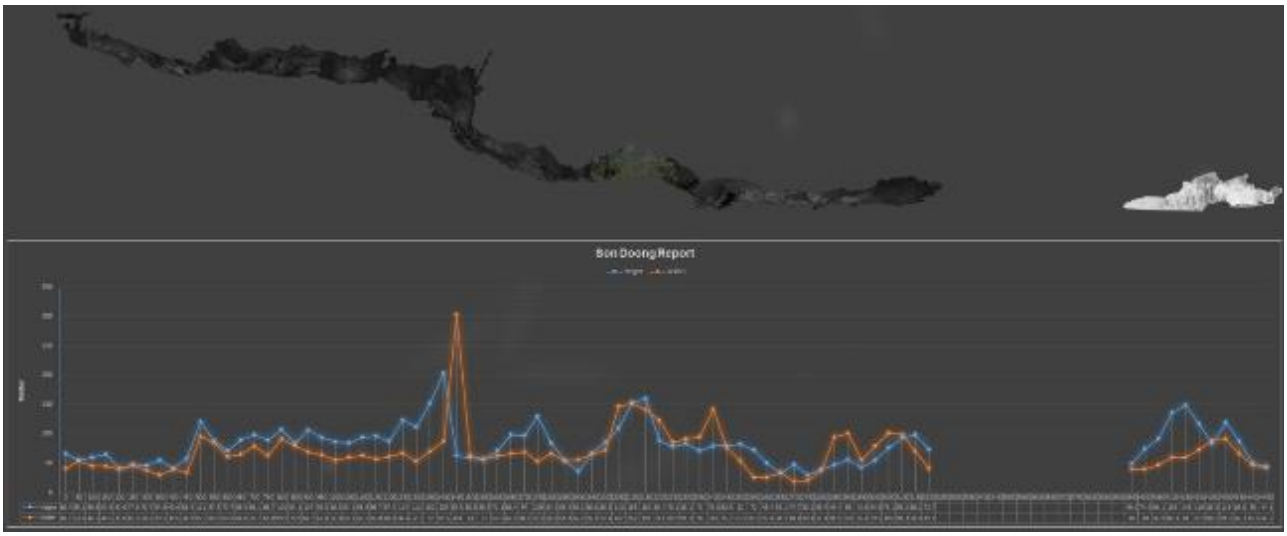
Shape and length of Son Doong cave



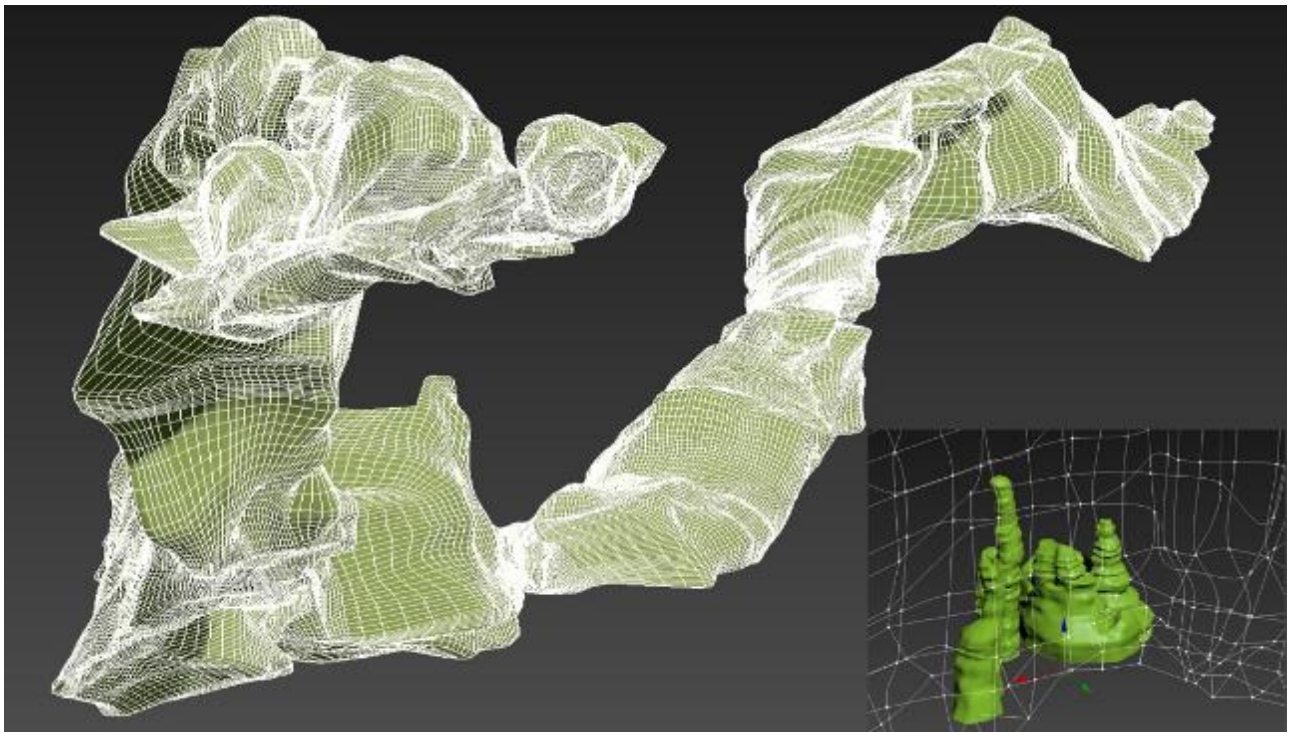
The different in elevation between lowest and highest point of Son Doong cave (742m)

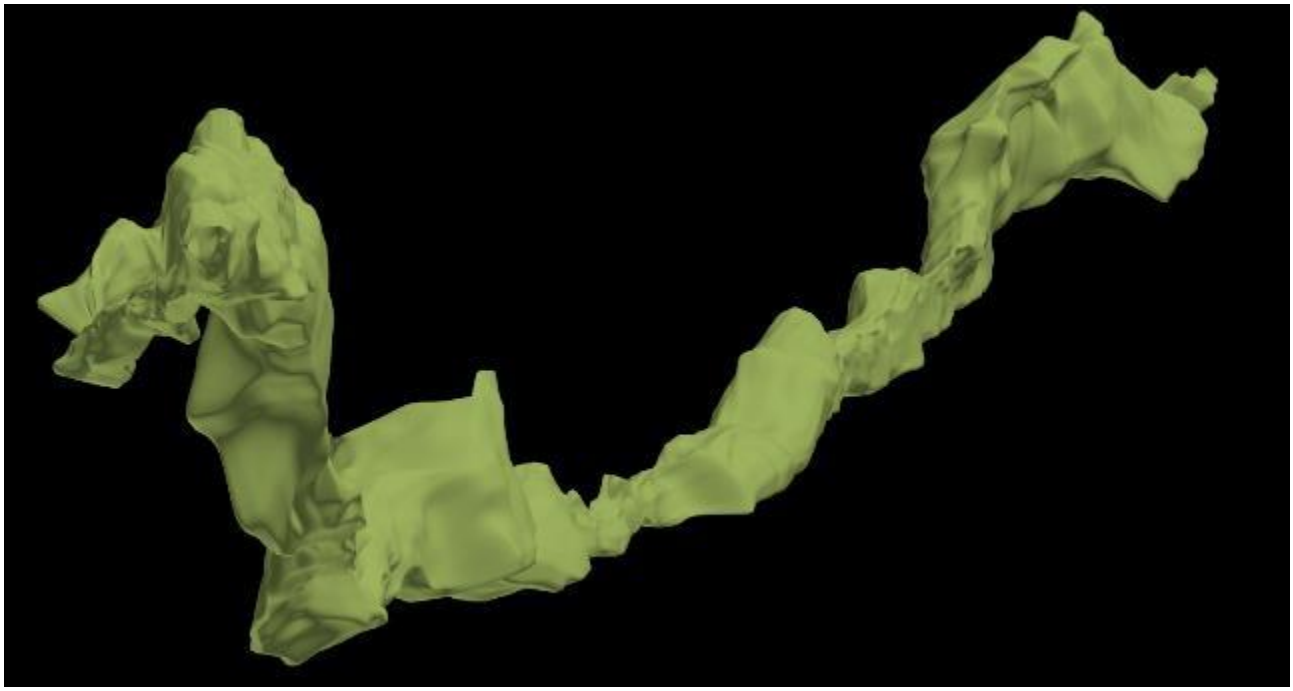


Son Doong cave view Top and Bottom

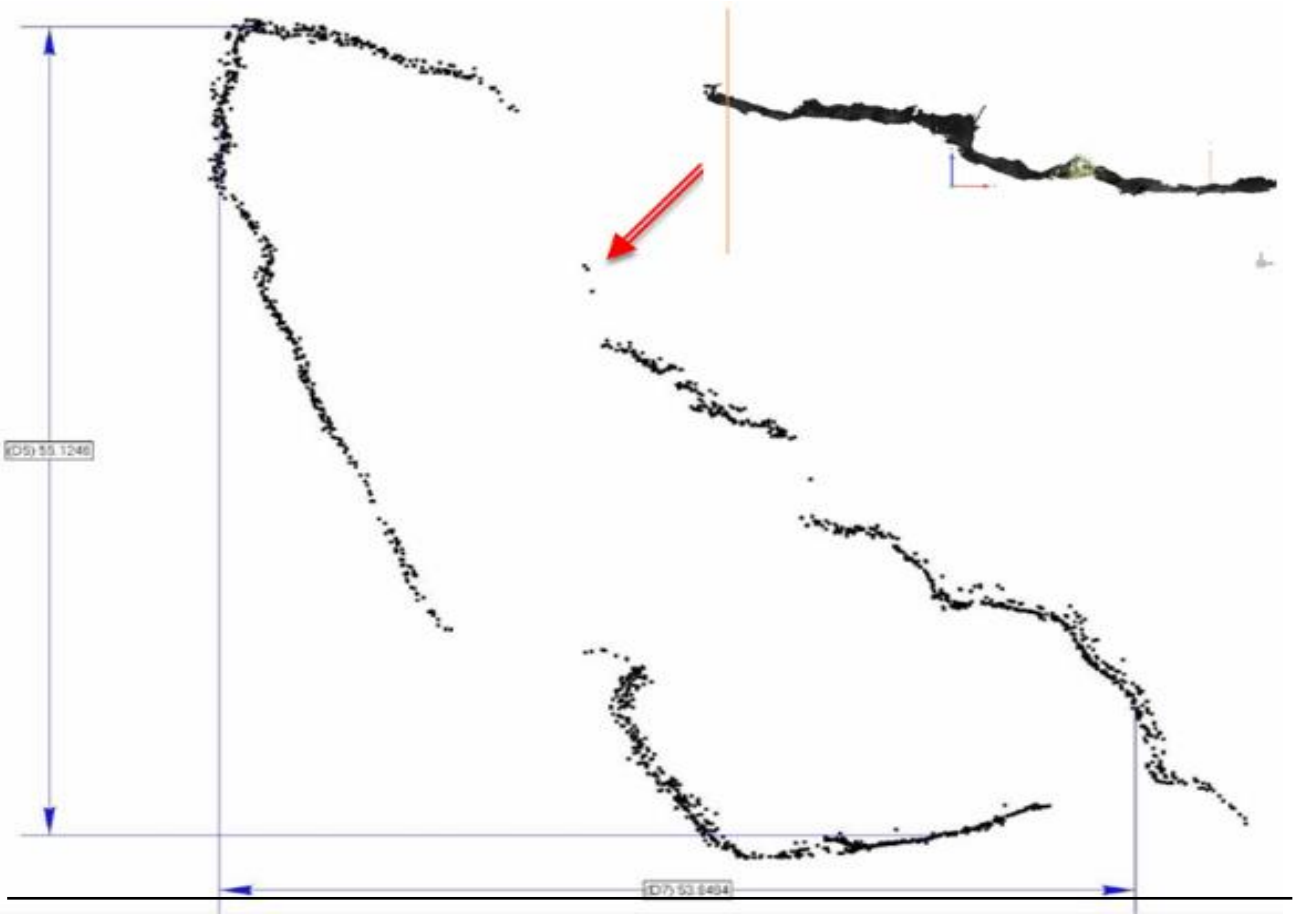


Height and Width of each cross section of Son Doong cave

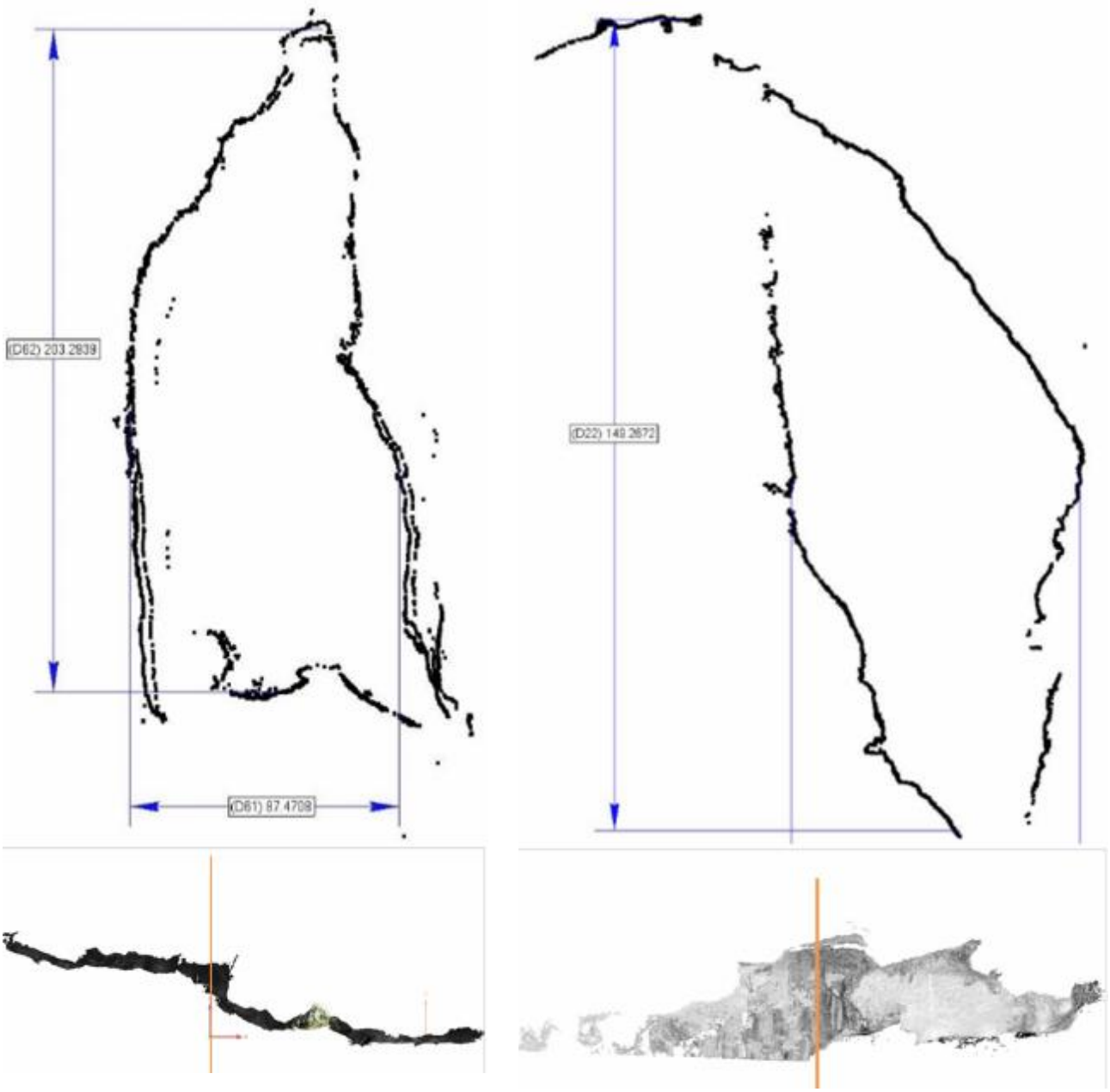




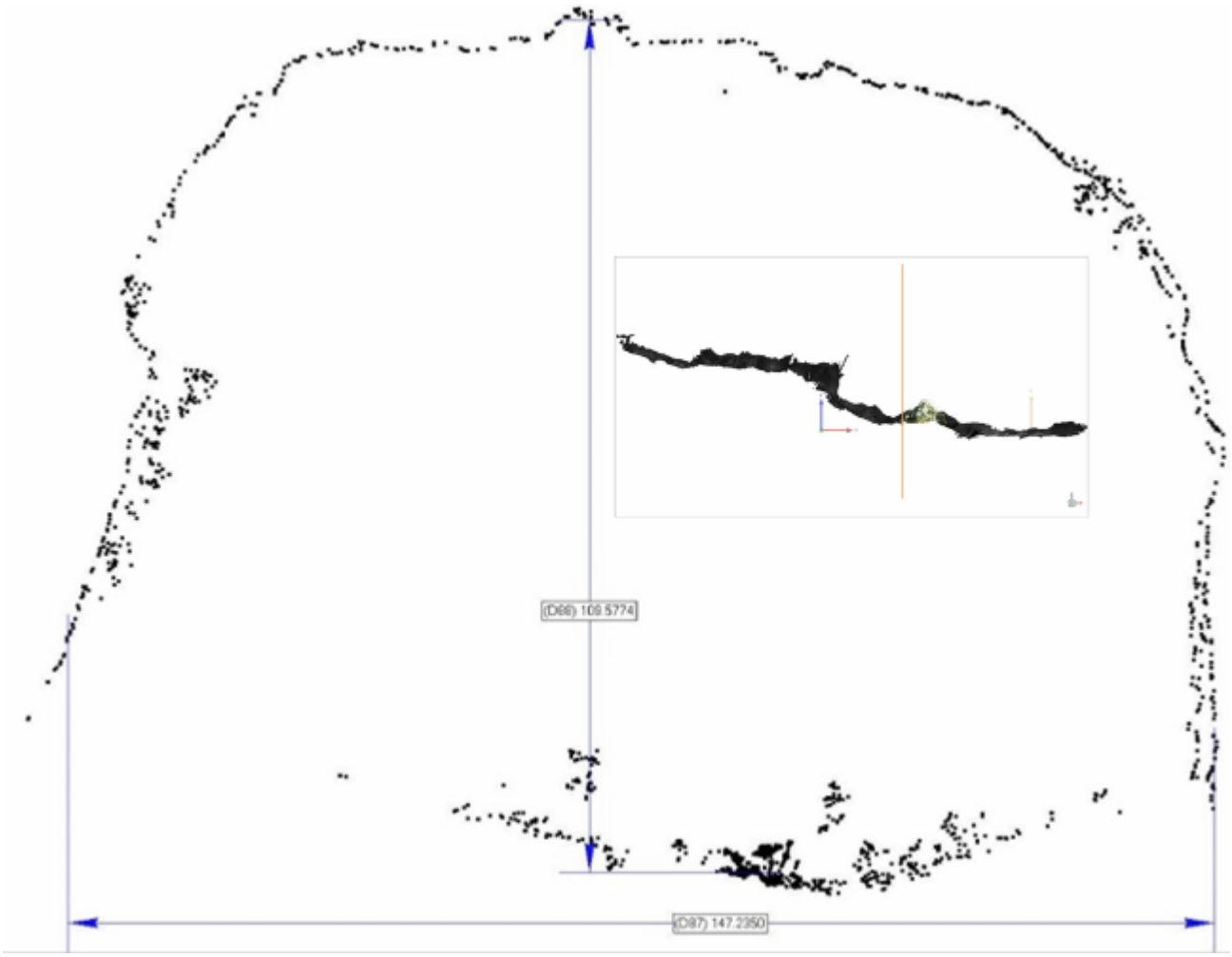
The shape of Son Doong cave solid model



Cross section at Son Doong cave entrance chamber (55.12 m x 53.64 m)



Highest point from bottom to ceiling 203.29 m (Left) and The Great Wall of Vietnam 149.28 m (Right)



Typical cross section point 147.23 m width at 109.57 m hight

The myth of Son Doong cave

3D model of Boeing 777 same scale inside one of many chambers of Son Doong cave

5. SON DOONG CAVE GENERAL UPDATE INFORMATION

Until now we have not get data for the Mud Lake at the end of Son Doong cave, but we can assume the size and shape of this section based on the measurement we got from handheld laser rangefinder to calculate and extract information. Below is general information about Son Doong cave that we got after processing data for VTV Special program, Vietnam Television:

- Location: Phong Nha Ke Bang National Park, Bo Trach district, Quang Binh province;
- Number of trips were made: 2 (the first trip in 2014 and the second in 2015);
- Survey method: Terrestrial 3D laser scanning & Laser rangefinder cross check;
- Number of scan station: 150;
- Number of entrance: 2;
- Number of doline: 2;
- Length of Son Doong cave: 4,450 meter (4.45 km);
- The lowest point from floor to ceiling: 18 meter;
- The highest point from floor to ceiling: 203 meter;
- The highest point from bottom to top of doline: 304 meter;
- The narrowest point (wall to wall): 18.8 meter;
- The widest point (wall to wall): 147 meter;
- The widest point (wall to another room): Up to 200 meter;
- Total volume of the cave: 12,500,000 m^3 (not included volume of Mud Lake).

6. CONCLUSIONS

In fact, we may use traditional survey equipment and methodology such as reflectorless total station, handheld laser rangefinder etc. to gathering 2D or 3D data, unfortunately we also recognized traditional survey cannot get enrich data as much as 3D laser scanner can. Here terrain of the Son Doong cave is absolutely difficult and finally almost sections of the cave are 100% in the darkness for 24 hours of a day that the reason why traditional survey method may not be used in some parts.

As we indicated from beginning, our Son Doong cave expedition is not a study tour, we made it by ordered from Vietnam Television – VTV Special Program since 2015. Instead of theory, we are focusing to the practical of 3D laser scanning among many potential applications and this project already showed the ability of modern survey technique took part from begin to the end of data collection, processing to model and rebuild shape of so large and complicated caving system as Son Doong.

In the trip to Son Doong cave, we used two brands of scanner Leica and FARO. Leica ScanStation C10 is reliable, strongly but really heavy with total weight more than 20 kg and it not easy for such small technicians to move between stations beside this C10 took about 20 minutes for each scan station without taking photo. While FARO (both X330 and S120) are small, lightweight and seem to be suitable for 3D cave data collection than C10.

And finally the use of 3D laser scanning technic will define a way to evaluate size, shape and volume of caves through clearly data. Beside this scanned database of the cave like Son Doong may

use to create many different type of deliverables for studies and applications as we did in last few years. Beside Son Doong cave, in 2015 we finished the same job at Paradise Cave, Phong Nha – Ke Bang jungle, Quang Binh province with the length nearly 8,000m.

Teams in front entrance of Son Dong cave (Author in red t-shirt, middle of second row)

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BIOGRAPHICAL NOTES

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