### Use of (primarily) Recon-3D in Scene and Vehicle Documentation

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for

### **SATAI 2024 Fall Conference**

Southwest Association of Technical Accident Investigators October 25-26, 2024 Glendale, AZ

## Use of (primarily) Recon-3D in Scene and Vehicle Documentation Daniel W. Vomhof III

- ACTAR # 484



- Involved in AI/AR work since 1976



- EIT





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## Recon-3D & Cloud Compare

 Because it is what I use, this presentation will concentrate on the Recon-3D app as a hand held scanner device.

\*It is expected that most of what I say about Recon-3D will also apply to the two other apps that will be mentioned.

\*This is not meant as a sales pitch, but as guidance as to things to think about if you go a "hand held" route.

# Recon-3D & Cloud Compare

- \* This is not the typical Recon-3D and Cloud Compare presentation. For typical Recon-3D presentations (which ARE important) see the Cloud compare comparisons-Patrick\_Davis.pdf and the WYMAN Symposium Lidar App.pdf presentations that are included as PDF's after this presentation, as well as the presentation to SATAI by Eugene Liscio earlier this year.
- This presentation is geared specifically towards the vehicle accident investigation and reconstruction field.

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# Recon-3D & Cloud Compare

\*This presentation deals with considerations as to equipment, app operation, selection, "issues" and accuracy within the Recon-3D tool.

\*The Cloud Compare portion takes the user through the steps to obtain crush measurements with Cloud Compare.

\*Both sections are based upon my experience working with the tools, you may have, or find, better methods.

# Hand Held Device Scanner Apps

 Because all of the apps I am familiar with use, to a greater or lesser degree, a LIDAR function, right now they need an Apple iPhone or iPad with LIDAR capability.

\*There are 3 apps of which I am familiar -\*Pix4D Catch \*PolyCam \*Recon-3D



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## **Pix4D Catch**

\*I am told the software is "free". However, in order to process, you need a Pix4D license

\*A potentially good option for those who already use drones, have a Pix4D license, and want to "catch" some evidence without breaking out the drone due to time, effort, or inability to get flight clearance.

### PolyCam https://poly.cam/



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# PolyCam

**\***Similar to Recon3D **\*** Uses Lidar and Photogrammetry **\***Annual License less than Recon3D \*While used, and found to be reasonably accurate, they are not putting the time, effort, and resources to validate the scans for forensic purposes (at least not to my knowledge). Therefore you MAY, MIGHT, ALMOST PROBABLY, will have to do additional validation on your own.



What is it? What is it not? Why use it?

 Recon-3D is an Apple App to be used on either an Apple iPhone or Apple iPad that has the LIDAR function.

\*It combines the LIDAR measurement function with photogrammetry using the video taken while "scanning" the object/area of concern.

## Recon 3D What is it? What is it not? Why use it?

\*It is not meant as a replacement for a "real" scanner (i.e. - FARO, Leica, etc) **\***It does not have the density of scan points the larger scanners have \*It also doesn't require the tripod or multiple scans of the larger scanners **\*It doesn't have the associated costs of** the larger scanners.

What is it? What is it not? Why use it?

**\***Cost - relatively low

\*Flexibility - You walk around and scan, you cover the area of interest, you don't have to set up a tripod multiple times, you don't need to pick up and set down the scanner multiple times, you just walk around and scan.

What is it? What is it not? Why use it?

- \*Time In many instances you can cover the area of interest in 2 minutes or less.
- \*"Accuracy" the accuracy is at least as good as a rolling wheel, and often many times better.

\*Documentation - it allows for documentation of area data for later possible use with minimal cost

### Screens







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5 Additional Scans

\*Both Annual and Monthly plans are available

\*30 Cloud uploads allowed per "month". Resets on the day of month you purchased the plan if it is an annual plan

 Additional uploads are available for purchase if you have a heavy use month.

★When you click the "+" button, you are presented with the SCAN SETTINGS. These are, per the most recent training, is the settings to be used by the CLOUD processing.

#### 🛜 Sync via Wifi Daniel Vomhof Daily Uploads Available: 10 Monthly Uploads Available: 17 Scan Settings Start/Stop Tone 1 side post 2 Standard Mode Default unit: IN Change Created On: 2022-07-25 11:00:13 AM Mode Standard Photogrammetry 3post Scan Density (mm) 0.195 inch (5.0 mm) Standard Mode Created On: 2022-07-25 10:51:40 AM 30 Depth of Reconstruction 196.85 inch (5.0 m) 4post Standard Mode Created On: 2022-07-25 10:20:14 AM **Target Detection** 1 post-2 Standard Mode Created On: 2022-07-25 09:14:36 AM **Target Distance** 0.0 IN ~ SAVE SCAN SETTINGS

Screens

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Screens **\***Units - I use INCHES, also available are METERS, FEET, and CENTIMETERS \*Mode - In general you will want to use STANDARD which is the melding of the photogrammetry with the LIDAR **\*SCAN DENSITY - Due to** recent changes, you will probably want 5 mm



Screens \*Scan Density - "tighter" densities (1,2,3,or 4 mm) can be set, but you will not be allowed to scan for the "full" 10 minutes

 Depth of Reconstruction -This is how far into the distance will be included. In general 5 meters (~15 feet) will be sufficient for vehicles and small scenes. (more later)



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**\***Target Detection - If you are using the APRIL targets to help set scale in your scan, you want this ON, however, for a variety of reasons, OFF has become my preferred mode. I have not seen a negative hit in my scans by not using the targets. (More later)



**\***Target Distance - For a variety of reasons, when using the April targets, I set my targets at 72 inches. If you have the ability to utilize a larger distance for scenes and vehicles, it would be advisable to do so, as it is always better to interpolate rather than extrapolate.



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\*SAVE SCAN SETTINGS · You have to save the settings in order to proceed.

\*The Settings we just walked through were set from the main menu. By setting the settings here, it saves time in the field, as the "base" settings are pulled up for each scan.



\*The base settings can be changed as a "one off" for individual scans (such as increasing the depth of reconstruction for larger scenes)

Help		>
Buy Plan		>
Change Password		>
Default Settings		>
Print April Tags		>
Contact Us		>
Terms & Conditior	IS	>
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Powered By	EveryPoint*	
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⋆To start a scan, click the "+" button, which then brings up the NEW **PROJECT NAME** screen. It is advisable to name your scans instead of going the "date-time" route



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 This is the name I am using for a scan of my 2004 Hyundai Santa Fe for this presentation.

\*Settings used for the scan are 5mm, 5m, No Targets.

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\*This sample scan took 1 minute 10 seconds to complete, that is 3 circuits around the vehicle. The 08:50 showing is the time remaining for the possible 10 minute scan time.

 Click the white circle with the square to stop the scan



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\*When you stop the scan you are presented with this screen. Given that I have completed a (in theory) "successful scan" I **ALWAYS ALWAYS ALWAYS** select SAVE FOR **LATER.**The other selection I may make is RESTART. This is done when I have problems mid scan.



What's Next?What would you like to do?PROCESS ON DEVICEPROCESS ON CLOUDSAVE FOR LATERRESTARTCANCEL

\*Once the scan is saved, you can click on it and then either process on your device, or process on the cloud, or both.



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- ★ If you decide to process on the cloud, it uploads and processes using the settings input prior to your scan.
- ★ If you choose to process on the device you are again presented with the settings in case you want to change any settings for the "on device" processing.
- The processing starts out showing you the video recorded as part of the scan. The next several pages are frame grabs of the video.









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\*Processing on the device goes through 7 "passes".

\*To process this scan on my iPhone 12 Pro took 33 minutes.

\*Some screen grabs of the processed point cloud follow -



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\*Note the "Fairy Dust" around the vehicle, especially the roof. Some of this is due to not using a monopod.

 Another part of this is processing on the device. Most of the "fairy dust" disappears with cloud processing.

To that end .... equipment.

### Equipment

\*The basic equipment which you need is .... the Lidar capable Phone or Tablet.

Other pieces of equipment that make life easier and better are Monopod
Phone Clamp
April Tags for Recon-3D
Add on Lights
Battery and "longer" power cable to keep device charged.

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Equipment - Phone/Tablet

\*While a tablet has more "horsepower" for processing scans

\*A phone is lighter and more portable, which can be a significant consideration.

\*In either case, LIDAR is needed.


Equipment - Monopod \*"Any" monopod will do ... however ... some considerations are - easily shortened/lengthened? Light in weight? Will stand up to repeated use? Storage? Transporting (on a plane)?

 Logree VR monopod, however, it is no longer available on Amazon

#### Equipment - Monopod



#### Other sticks are available, including the presumably "current generation" VR stick.

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#### Recon 3D Equipment - Monopod



The stick on the far right has a tripod "foot" included which may be desirable if you need to set the stick down in between scans.

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#### Recon 3D Equipment - Monopod



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✓prime Two-Day FREE Returns ✓ Save up to 3% with business pricing. Sign up for a free Amazon Business account
S Best price

Thank you for being a Prime Member. Pay <del>\$21.97</del> **\$0.00** for this order; **get a \$200 Amazon Gift Card** upon approval for the Amazon Business Prime Card. Terms apply. Learn more

May be available at a lower price from other sellers, potentially without free Prime shipping.

Style: 1-Pack

Configuration: 1-Pack

Brand Amazon Basics Color Black Compatible Camera Devices



\*I have had good luck with "Amazon Basics" products, and this monopod has all the items needed(i.e. - 1/4 inch screw, easily extendable, etc) and the price is "right".

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Roll over image to zoom in

#### **Equipment - Phone Clamp**

Electronics > Camera & Photo > Accessories > Tripod & Monopod Accessories > Camera Mounts & Clamps



NEEWER Metal Phone Tripod Mount Adapter with Arca QR Base, Cold Shoe, 360° Swivel 180° Tilt, Phone Holder Compatible with iPhone 15 Pro Max Galaxy S24 Visit the Neewer Store 4.7 \*\*\*\*\* \* 414 ratings | Search this page Amazon's Choice

5% off with qualifying purchase Shop items > S Best price

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# \*A clamp will be needed to hold the phone at the end of the monopod

Equipment - Phone Clamp - Lights

- \*This is the one I use (or its previous
  generation)
  \*Metal clamp
  - \* Easy to get phone in and out
    \* "Shoes" to hold up to 3 accessory lights

\*The grip pads on either end of the holder have a tendency to "slide" with use and using the device in a "hot" environment.

Equipment - Phone Clamp - Lights

\*Be prepared to reglue the pads using some type of "super glue" that wont be as susceptible to heat.



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Equipment - Phone Clamp - Lights

 Lights .... they can be helpful, but ...
 I don't use them. Within my working environment .... I just don't need them enough to warrant buying and lugging them around.

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Equipment - Battery and Chord \*One of my working environments is scanning vehicles at Auto Shows (more on this in a bit)

- \*As such, I will scan 50+ vehicles is a "day".
- \*In order to do this .... I need more battery life than the phone will give, so ...

\*External battery in a vest pocket with a 10 foot chord.

Equipment - Battery and Chord \*While you may not need to charge while you are scanning

\*You should be prepared to charge your phone if you end up having to do a large scene, multiple scene/vehicles, or just have a long day. You DON'T want to run out of power when you need the phone/tablet for a scan.

**Equipment - April Tags** \*Recon-3D has a specific set of April tags you can download and printout. \*You can also purchase a "April Tag Kit" from Recon-3D \*The theory is, you set the tags at a known distance, input that distance into your device before beginning the scan, then scan.

# Recon 3D Equipment - April Tags

\*Having the known distance included in your scan will, in theory, improve the accuracy of the scan processing, and thus your resulting scan.

\*Unfortunately, I have found that the April Tags did NOT improve my accuracy, and at times, I actually had worse accuracy using the tags.

# Recon 3D Equipment - April Tags

Another issue with the tags is/are If multiple people are using Recon-3D, and
 All are setting out tags, most probably at differing distances

\*The program gets confused, and in the end ... you get no scan.

\*I found this out at WREX 2023 with the car sandwiched between the semi and bus.

# Recon 3D Equipment - April Tags

 Last issue is - working environment.
 If you are working where there are lots of people, the likelihood of your tags being kicked, and thus the distance changed, is high.

\*For all of these reasons, I don't use the tags.

Working Environment \*For those who have never been to an Auto Show .... here are some pictures from the Orange County Auto Show from this year ....



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#### Working Environment

#### Thank you for attending the OC Auto Show! We hope to see you next

veai

dired.

> More Brands and More Fun!

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AUTO

SHOV

Working Environment - Issues **\***Heat - The hotter the environment, the quicker the device will be to overheat. ★At IPTM this year temp was ~90 degrees F, humidity was high. We did 9 ped crashes in about 2.5 hours. The only way I was able to accomplish this was because I had 2 phones. So ... 2 tests, switch phones, while the first cooled down, 2 more tests, etc. etc.

Working Environment - Issues \*Heat - IF you have a phone case, and I think if you don't you are asking for trouble, but if you have one, the heat builds up faster.

\*Heat - as already mentioned, heat and the glue used for the non-stick clamp pads are not compatible.

\*Heat - trying to do a "quick" device process to check your scan(s) .... may render your device unusable due to overheating.

Working Environment - Issues **\***Battery - The battery on the phone can be quickly used up. Especially if you are trying to do "quick" (i.e. - 30 mm resolution) device processing to check your scan(s). Make sure you have a way to charge your phone "on site" if needed.

 Black/Shiny - Black vehicles are a problem, especially if clean and shiny.

#### Working Environment - Issues - Black Vehicles \*Device process - vs - Cloud Process











#### Working Environment - Reasons to Use

#### **\***Tree cover





**Cloud Process Settings** 

Mode				
Standa	rd Photog	ramme	etry	
Resolution		C	0.195 inch (5.0 mm)	
Scan Dur	ation: 261 secs	\$		
Depth o	f Reconstruct	tion	196.85 inch (5.0 m)	
Target D	etection			

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#### Recon 3D Working Environment - Reasons to Use



#### Working Environment - Reasons to Use **Terrain issues**



#### Recon 3D Working Environment - Reasons to Use \*Terrain issues



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#### Working Environment - Reasons to Use \*More Terrain Issues



#### Working Environment - Reasons to Use \*More Terrain Issues



Working Environment -Reasons to Use

\*Distance/Setup Issues
\*Resolution - 5 mm
\*Depth - 10 m
\*Time of scan - 257
seconds = 4 min 17 sec



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#### Recon 3D Working Environment -Reasons to Use \*Distance/Setup Issues



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**Recon 3D** Working Environment -**Reasons to Use \***Distance/Setup Issues \* While admittedly not the "Cleanest" in the periphery, it captures the needed data for a basic diagram. \* When the person running the "real" scanner asked about getting the "helmet", the reply was "eff that!" How many times has something similar occurred in a "real" scene?  $\star$  If a more complete scene periphery is required, a drone flyover can be conducted and merged, as long as it is done before most of the roadway features (cracks) are still there.

#### **Recon 3D** Scanning SOP - Vehicles

#### \*In general -

- ★ 3-4 "loops" around the vehicle
- \*LOW for the most part, the lower the better - the monopod is as helpful for this as it is for "high"
- MEDIUM roughly between chest and eye height
- \*HIGH As close to directly over the vehicle as possible
- \*HIGH Angle High, but at about a 45 degree angle to roofline. This can be combined with opposite direction.

 Scanning SOP - Vehicles
 \*When scanning damaged vehicles especially, you want to make sure you do at least one loop in the opposite direction of the rest of your loops. This helps to show the areas that might (almost always are) "shadowed" with your "normal" loops.

\*If the damage is complicated, you might want to spend additional "back and forth" time in the damage area before your scan is completed.

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Recon 3D Scanning SOP - Vehicles \*For an undamaged, exemplar "car" vehicle, typical scan time is under 3 minutes if there is minimal human interference (see Auto Show pics). \*Damaged vehicles can usually be

scanned in about the same amount of time.

 Damaged vehicles can typically be scanned as part of the scene scan, especially if there is separation between vehicles.

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Scanning SOP - Scenes \*To a point, higher is better \*I am typically scanning at about 10 feet high

\*Phone should be pointed to the ground with somewhere between a 30-45 degree angle between phone and ground.

Try and walk both sides of the vehicle path, as well as down the center.
Do at least two loops around the vehicle(s).

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 Scanning SOP - Scenes
 \*Looping around the vehicle helps to set you up on the return path to the AOI.

 After the basic post impact path is walked, you may want to "criss-cross" across the path to fill in the periphery and possible debris

Scanning SOP - Scenes
\*Some people have found that the scan comes out better if the camera is always oriented in the same direction (i.e. - always pointed "North", etc.)

★I have not found that to be the case. HOWEVER -

\*You do not want to do a rapid "spin in place" when turning, this will more often than not cause the scanner software to lose track of itself

Scanning SOP - Scenes

\*Instead, turn by moving in an arc around things.

★GO SLOW when turning, slower than when walking in a straight line.

\*Experiment with doing a "drunken weave" path when walking the straight line to pick up more along the periphery.

\*DON'T be afraid to do a second, or even third scan.
Scanning SOP - Scenes
 \*After doing your overall scene scan, consider scanning smaller sections of the scene if they have data which may be critical. These can later be tied in to a larger overall scene.

\*Mark a Known Distance in the scene so that you can check on the scan "accuracy".

# Point Cloud - File Size \*All things considered, minimal size. RAW Point Clouds - Size

4N6XPRT Dropbox → Daniel Vomhof III → 2024 SCARS → RAW → Recon-3D Scans

1	Name	Date modified	Туре	Size
]	C 1-2013_Ford_Taurus.e57	7/22/2024 3:36 AM	E57 File	28,466 KB
	C 22019_Dodge_Charger.e57	7/22/2024 3:36 AM	E57 File	26,075 KB
	C 32014_Dodge_Charger.e57	7/22/2024 3:35 AM	E57 File	29,863 KB
	C 42016_Dodge_Charger.e57	7/21/2024 8:53 PM	E57 File	26,971 KB
	C 24_scars_1_post.e57	7/22/2024 4:30 PM	E57 File	22,795 KB
	C 24_scars_2_post.e57	7/22/2024 4:29 PM	E57 File	23,856 KB
	C 24_scars_3_post.e57	7/22/2024 4:30 PM	E57 File	23,044 KB
	C 24_scars_4_post.e57	7/22/2024 4:28 PM	E57 File	23,711 KB
	C 24_scars_ct2.e57	7/22/2024 4:34 PM	E57 File	146,308 KB
	@ 24_scars_ct2-2.e57	7/22/2024 4:33 PM	E57 File	85,758 KB
	C 24_scars_ct2-Trimmed.e57	7/22/2024 4:41 PM	E57 File	135,452 KB
	C 2013_Ford_Taurus.e57	7/23/2024 8:20 AM	E57 File	31,528 KB
	C 2014_Dodge_Charger.e57	7/23/2024 8:20 AM	E57 File	29,791 KB
	C 2016_Dodge_Charger.e57	7/23/2024 8:20 AM	E57 File	26,656 KB
	C 2019_Dodge_Charger.e57	7/23/2024 8:20 AM	E57 File	28,664 KB
	@ 2024_scars_ct1(1).e57	7/22/2024 4:34 PM	E57 File	113,366 KB
	C 2024_SCARS_CT1.e57	7/23/2024 6:43 AM	E57 File	113,367 KB
_		The second state of the second state of the		

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# Point Cloud - File Size \*All things considered, minimal size. Processed Point Clouds - Size

opbox ▶ Daniel Vomhof III ▶ 2024 SCARS ▶ 4N6XPRT\_Systems\_Data-SCARS\_2024 ▶ Recon-3D E57 Point Clouds

Name	Date modified	Туре	Size
S 1-2013_Ford_Taurus-2024_SCARS_PreTest.e57	7/23/2024 7:24 AM	E57 File	10,218 KB
22019_Dodge_Charger-2024_SCARS_PreTest.e57	7/23/2024 7:26 AM	E57 File	10,302 KB
S 32014_Dodge_Charger-2024_SCARS_PreTest.e57	7/23/2024 7:32 AM	E57 File	10,546 KB
S 42016_Dodge_Charger-2024_SCARS_PreTest.e57	7/23/2024 7:35 AM	E57 File	9,712 KB
S 2024_SCARS_CT1_Scene.e57	7/23/2024 6:46 AM	E57 File	112,467 KB
2024_SCARS_CT2_Scene.e57	7/23/2024 6:51 AM	E57 File	142,818 KB
S 2024_SCARS_V1-PostTest.e57	7/23/2024 6:57 AM	E57 File	10,789 KB
2024_SCARS_V2-PostTest.e57	7/23/2024 7:02 AM	E57 File	9,554 KB
S 2024_SCARS_V3-PostTest.e57	7/23/2024 7:15 AM	E57 File	10,613 KB
2024_SCARS_V4-PostTest.e57	7/23/2024 7:21 AM	E57 File	9,798 KB
F Crash Test 1 - Recon-3D Scan Error.jpg	7/25/2024 5:28 AM	JPEG Image	272 KB
Prash Test 2 - Recon-3D Scan Error.jpg	7/25/2024 5:42 AM	JPEG Image	403 KB
😹 Recon-3D Scan Comments.txt	7/23/2024 6:41 AM	Text Document	1 KB

### Recon 3D "Accuracy"



#### \*Note - No targets. However, wheelbase in the scan is 103.1 inches, wheelbase as we have it in Expert AutoStats is 103 inches.

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### Recon 3D "Accuracy"

\*What is important to us as Vehicle Accident Investigators??

\*Are the measurements reasonably correct?

\*Do the measurements obtained from the scans reflect the "real life" measurements?

\*Will the measurements obtained result in "correct" calculated values?

**\***To that end .....

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## Recon 3D "Accuracy" \*Ped Test at SATAI in 2023 \*Instrumented impact speed 34-37 mph



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## Recon 3D "Accuracy"



## Recon 3D "Accuracy"

## ★5.88-6 = -0.12 ★(-0.12/6)\*100=-2.0%



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## **Recon 3D** "Accuracy" \*64.83-65 = -0.17 \*(-0.17 / 65)\*100 = -0.26% (i.e. - less than 1%)

	Distance:         64.829164           ΔX         -64.773094         ΔXY         64.8255           ΔY         2.607025         ΔXZ         64.77767           ΔZ         0.685696         ΔZY         2.6956	39 26 93	
Distance: 64.829164 <u>AX</u> -64.773094 <u>AXY</u> 64.825539 <u>AY</u> 2.607025 <u>AXZ</u> 64.776726 <u>AZ</u> 0.655666 <u>AZ</u> 2.60502			*
42 0.003090 421 2.093093			

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### **Recon 3D** "Accuracy" \*70.789-71 = -0.211 ft \*(-0.211/71)\*100 = -0.29% (i.e. - less than 1%)



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 \* In multiple instances I have "measured" a 72 inch distance in Recon-3D. I generally find that I get a distance within +/-.75 inches.

- $\star$  (0.75/72)\*100 = +/- 1.0%
- From the SATAI test it can be seen that the accuracy is, for that test, -2% or better.
- Think, rolling wheel, tape, pacing how often have you been MORE THAN 2% off? Less than? Have you ever checked to see?

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"Accuracy"/Error Rate
\*Some additional Scene scans, with known distances in the scans, and the error rate calculated.

## Recon 3D "Accuracy"/Error Rate

Crash Test 1 25 feet = 7.62 m (7.578 - 7.62) / 7.62 = -0.55% (7.561-7.62) / 7.62 = -0.77%



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#### "Accuracy"/Error Rate

Crash Test 2 25 feet = 7.62 m (7.649 - 7.62) / 7.62 = 0.38% (7.654 - 7.62) / 7.62 = 0.44%



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\*Accuracy"/Error Rate
\*As mentioned previously, there were 9
"ped" tests completed at IPTM in 2024.

\*To evaluate how "critical" the errors experienced in the Recon-3D scans may be, speed calculations will be made using a "Lawn Dart" calculation.

\*The calculations are for illustration purposes, using the simplest of the various formulas.

\*This is NOT a Ped class, if you prefer using other formulas, be my guest!

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"Accuracy"/Error Rate

- \*The Formula used is the 45 degree vault formula.
- ★MPH = (3.87 \* Throw) / SQR(Throw +/- Height)
- Throw distance is as measured in Recon-3D in Feet
- ★Height is assumed to be 0

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#### "Accuracy"/Error Rate

#### \*CT1- Error~-2%



# \*MPH = 38.0 +/-2% = 37.2-38.7 \*RADAR = 34 MPH



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``Accuracy''/Error Rate
\*f=0.6, MPH = 35.4 | f=0.75, MPH=38.6
\*+/- 2% 34.7-36.1 37.8-39.4



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## **Recon 3D** "Accuracy"/Error Rate **\*CT2- Error~1.3%**



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"Accuracy"/Error Rate
\*MPH = 40.1 +/-1.3% = 39.6-40.6
\*RADAR = 43 MPH





#### "Accuracy"/Error Rate \*CT3- Error~2.8%



istance: 88.76946

3.564186

88.720886

88.697876

``Accuracy"/Error Rate
\*MPH = 36.5 +/-2.8% = 35.4-37.5
\*RADAR = 34 MPH

T3 - Throw Distance



#### "Accuracy"/Error Rate

#### **\*CT4 - Error~0.07%**



``Accuracy''/Error Rate
\*MPH = 41.2 +/-0.07% = 41.2-41.3
\*RADAR = 39 MPH



#### "Accuracy"/Error Rate

#### \*CT5 - Error~-1.6%



``Accuracy"/Error Rate
\*MPH = 39.1 +/-0.07% = 38.5-39.8
\*RADAR = 42 MPH



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#### "Accuracy"/Error Rate \*CT6- Error~-1.6%



"Accuracy"/Error Rate \*MPH =32.5 +/-0.07% = 32.0=33.0 \*RADAR = 32 MPH



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## **Recon 3D** "Accuracy"/Error Rate \*CT7- Error~-0.3%

★ Judged to be an "invalid" test, so limited data collected. However, it's a "real" ped crash to the officer arriving on the scene.



"Accuracy"/Error Rate \*MPH = 34.0 +/-0.07% = 33.9-34.1 \*RADAR = 42 MPH



## Recon 3D "Accuracy"/Error Rate

### \*CT8- Error~0.90%



# ``Accuracy"/Error Rate \*MPH = 38.2 +/-0.07% = 37.9-38.6 \*RADAR = 42 MPH



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#### "Accuracy"/Error Rate

#### **★**CT9 - Error ~1.4%



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# ``Accuracy"/Error Rate \*MPH = 35.5 +/-0.07% = 35.0-36.0 \*RADAR = 32 MPH



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"Accuracy"/Error Rate

- The number of examples shown was to illustrate
  - \*A The "error rate" isn"t constant, but
  - \* B The "error rate" of the scan is low enough that it has minimal impact on the collision analysis
  - \* C The minimal "error rate" I am experiencing, WITHOUT April Targets, is not a fluke
- The next slide summarizes these calculations
## **Recon 3D**

"Accuracy"/Error Rate - Calculation Summary
\*Assume a max error of -/+ 3%
\*What does that do to the speeds?

		IPTM 2024 Ped Crash Test Calculation								
Lawn D	art Formula =	Speed = (	3.87*Distance)/S	QR(Dist +/-	Height)					
Assume Height=0					Lawn					
an in the fact had dead on the	Recon-3D measurements				Dart					
	Throw	Skid	Measurement	RADAR		Speed			S	kid
	Feet	Feet	Error %	MPH		MPH	Error - 3%	Error +3%	f = 0.6	f=.75
CT1	96.20	69.6	-2.00	34		38.0	36.8	39.1	35.4	39.6
CT2	107.30		1.30	43		40.1	38.9	41.3		
CT3	88.76	1	2.80	34		36.5	35.4	37.6		
CT4	113.50		0.07	39		41.2	40.0	42.5		
CT5	102.30		-1.60	42		39.1	38.0	40.3		
CT6	70.40		-1.60	32		32.5	31.5	33.4		
CT7	77.00		-0.30	42		34.0	32.9	35.0		
CT8	97.68		0.90	42		38.2	37.1	39.4		
CT9	84.20		1.40	32		35.5	34.4	36.6		

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# **Recon 3D**

"Accuracy"/Error Rate

\*IF you mark out a known distance at a scene, you can then determine a error rate for your scan as was done in the examples

\*HOWEVER, note the first two examples, different error rate for two measurements in same scan.

\*Your error rate will be determined as much or more by the "points" you pick, or are allowed to pick, as it is by the scan itself.

## Cloud Compare Trim, Clean, Scale \*Now that you have a Point Cloud, What next??



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\*One piece of software that will allow you to view and edit the point cloud.

\*Once you have the E57 file, processed on either your device or the cloud, it needs to be cleaned up and scaled to the preferred units (if using Cloud Compare). The units when first imported into Cloud Compare is METERS.

\*1 Meter = 3.28084 feet

\*1 Meter = 39.37008 inches

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## Cloud Compare Trim, Clean, Scale - Unit Conversion \*1 Meter = 3.28084 feet \*1 Meter = 39.37008 inches

## These conversions come from a utility software program called CONVERT

Force	About	Speed
Acceleration	Convert Version 4.05	Ce Flow
furlong hectomete inch kilometer lightyear megapars meter (m)	Copyright © 1996-98 by Joshua F. Madison josh@joshmadison.com http://www.joshmadison.com/software	
	UK	

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## Cloud Compare Trim, Clean, Scale - Unit Conversion

- ★ 1 Meter = 3.28084 feet
- \* 1 Meter = 39.37008 inches

Keep in mind that when you have done a good job, the other side will attempt to 'blow smoke" and confuse the issue. So, be aware, there are other interpretations of what the conversion "should" be. Google "meter to inches" to see some of them. In the end, these other conversions amount to "how many decimal places does your calculator display?" i.e. -"The speed of the vehicle calculates out to EXACTLY 33.45672319 mph ..... exactly."

Most "Good" CAD software packages have the capability to handle Point Clouds. Cloud Compare is being used here because it is, well, "FREE", and is also a well featured piece of software.
Cloud Compare can be downloaded

from -

https://www.danielgm.net/cc/release/

\*The first video will illustrate what needs to be done.

\*Please note, when trimming, to place points, left click on your mouse, to "close" a "loop", right click on your mouse.

★ Play Video 1 in "Cloud Compare videos" folder - All videos are without sound, you just have to watch the mouse movements.

\*The second video shows the same vehicle after the crash test, trim, rotate, and scale the point cloud.

★ Play Video 2 in "Cloud Compare videos" folder



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\*Now that both vehicles are trimmed, they need to be aligned so that a crush "slice" can be generated.

★ Play Video 3 in "Cloud Compare videos" folder



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\*Once aligned, a slice can be taken from which crush measurements can be obtained.

★ Play Video 4 in "Cloud Compare videos" folder



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 Once a slice has been obtained, and the vehicle is aligned along with the X-Y Axis, crush measurements can be obtained

★ Play Video 5 in "Cloud Compare videos" folder



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 Final Crush Measurements for all 6 vehicles involved in the three SCARS Crash Tests conducted in July 2022 follow

\*As stated on the slides \*The X dimension = the Crush Depth
 \*The Y dimension = the incremental Crush
 Lengths
 \*The UNITS = inches

## **\*V1** Crush Measurements



## **\*V2 Crush Measurements**



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## **\*V3 Crush Measurements**



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## **Cloud Compare** Crush Measurements **\*V4 Crush Measurements**



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## **\*V5** Crush Measurements



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## **\*V6 Crush Measurements**



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**Cloud Compare** Supplemental Material - Exemplar Vehicles \*When working in a Crash Test environment, I/you have the luxury of scanning the vehicle Pre-test as well as Post-test.

\*But what do you do in a "real" crash to get your exemplar, undamaged, vehicle?

\*You can search around and tray and find one that the owners will allow you to scan. OR .....

## **Cloud Compare** Supplemental Material - Exemplar Vehicles **\*Lightpoint - i.e. - Lou Peck**

#### https://lightpointdata.com/laser-scanned-exemplars#!



1,260 Exemplars Currently Available (\$545 for most models)

Elevate your video, photogrammetry, crush, simulation, and biomechanical analyses with a Lightpoint exemplar point cloud. Each package includes a cleaned point cloud of the vehicle's interior and exterior (.pts format), registration report, scanner calibration certificate, and photographs.

Product Video | Sample Point Cloud | Tutorials

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How can we help?

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## **Cloud Compare** Supplemental Material - Exemplar Vehicles **\*car-clouds.com**

#### \* https://car-clouds.com/



#### About Us

Car Clouds is dedicated to offering high-quality 3D laser scanned point clouds of vehicles to the accident reconstruction, 3D modeling, video game, and digital art industries.

Our extensive (and growing!) library of scans covers common interchanges of passenger cars, as well as a huge selection of medium and heavy-duty commercial vehicles, heavy equipment, trailers, motorcycles, bicycles, and even mobility devices. Most vehicles include interior scans, too.





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# **Cloud Compare**

## Supplemental Material - Exemplar Vehicles \*4N6XPRT Systems

## \*https://www.4n6xprt.com/point-clouds/



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## Cloud Compare Supplemental Material \* www.4n6xprt.com/SATAI\_2024.htm

**Daniel W. Vomhof III** 

Presentation Materials for

#### **SATAI 2024**

#### **Recon-3D & Cloud Compare for Vehicle Accident Investigators**

Download Recon-3D & Cloud Compare Presentation - 1 Slide per page

Recon-3D supplemental Videos/Material

2010 Hyundai Elantra "Walk Around"	Environment - Footpath near Cape Coral Florida		
Walk Around MP4 video	Scan Settings for this SCENE scan		
Walk Around E57 Point Cloud - RAW	Video produced by scanning		
Construction of the second	Footpath E57 Point Cloud - RAW		

#### Cloud Compare Instructional Videos

Movies - No Sound - Of Mouse Movements and Screen Menu Commands/Key Strokes

Please note that the videos may take some time to download

Video 1 - Trim, Align, and Scale Pre Test (Exemplar) Vehicle

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#### DIGHTPOINT



#### SPEND YOUR TIME ELSEWHERE.

#### OUR VEHICLE POINT CLOUDS



#### **Expansive Database**

there are over 1,200 exemplar vehicle point clouds currently available, ranging from 1987 to today



#### **Fully Cleaned**

each exemplar is fully cleaned with the precision of a surgeon



#### Inside and Out

the interior and exterior of each exemplar is always scanned



#### Reliabilty

each vehicle is scanned using a thorough and uniform process, creating complete and consistent data If you've ever tracked down an exemplar, you know it takes hours of searching for the perfect model, awkward conversations with dealers, and usually some cash to persuade the owner. Then back at the office, it takes a couple more hours to stitch and clean the data.

"Time is the most valuable thing a person can spend," don't waste yours doing work that's already been done.

Lightpoint is the **gold standard** of exemplars. All vehicles are measured with a top of line scanner, Leica's RTC360, so no one in the community has to do it again. Our exemplar package includes high quality photographs, a point cloud file (.PTS format), a registration report from Leica's Cyclone, VIN info, and an upto-date calibration certificate for the relevant scanner.



#### www.lightpointdata.com







#### Car Clouds is dedicated to offering high-quality Leica and FARO 3D laser scans of vehicles, registered with forensic accuracy.

Our growing library of 750+ scans covers common variations of:

- Passenger cars
- Medium & heavy-duty commercial vehicles
- Heavy equipment, trailers
- Motorcycles, bicycles, mobility devices

The same scans you make for your own cases, downloaded in seconds! When time and efficiency count, *car-clouds.com* is at your fingertips.



#### THE PRODUCT

We are now offering a new resource to our customers at what we believe to be a reasonable price. We are currently offering our models for the price of \$100.00 USD per model.

The models are to be purchased through the online shopping cart, and downloaded directly to your computer. We have placed no "locks" on the actual models, so our anticipation is that there is no need for you to purchase more than one of any model at a given time, as you can just reuse the single model purchased (as long as you don't make significant editing changes). If you do happen to some how mess up the purchased model, you can download the purchased model up to 5 times within a 90 day time period.

The point cloud models are just that, point clouds. We do not offer the models in a mesh format at this time.

Our intent in offering this new service/product is to:

- \* Provide exemplar Point Clouds to our customers in a somewhat "universal" format (E57). The point cloud format can easily be converted using a program called CLOUD COMPARE if the user has a need to do so. This program can be downloaded at no charge from the internet.
- \* Provide the models at a reasonable cost, especially for the lower budget cases.
- \* Provide something that is Ideal for use as exemplars for crush analysis.
- \* Allow users to obtain detail dimensions not readily available through other means.

#### **CAUTIONS & LEGAL STUFF**

® Denotes a Trademark registered with the USPTO. All of the program materials are copyrighted under U.S. and International Law

• The E57 Point Cloud model is being provided **"As Is"**.

• We are not responsible for the mis-use or mis-representation of the scan data provided, nor the information extracted based on that mis-use or mis-representation.

• The Scan units were "inches". Depending on your Point cloud program, the import units may be Meters, Inches, or Feet. You should be sure to check a "known" dimension, such as wheelbase, to verify what your Point Cloud units are before working with the point cloud.

• The Point Cloud is provided "As Scanned". No Scaling has been done to the point cloud. If "exact" measurements are important to you, it is suggested that you scale the Point Cloud to match published or measured Overall Length, Wheelbase, or some other dimension that is important to you.

• Some manufacturers have production "problems" (eg – "deer hunter"/"deer hunting season" production or last minute design changes) which lead to dimensions on the actual vehicle which may differ significantly from published information for a specific vehicle, make, or model series.

• You DO have the right to bill your clients for the Point Cloud model as an expense.

• You DO NOT have the right to resell the point clouds purchased from us as your own product.

# POINT CLOUDS



offered by 4N6XPRT Systems®

8387 University Avenue La Mesa, CA 91942
Phone: (800) 266-9778
Fax: (619) 464-2206

email: <u>4n6@4n6xprt.com</u>



You can enter the Point Cloud Shopping Cart page through two different "portals" on our web site, one along the top menu bar, the other down the right side menu bar.

#### 4N6XPRT A Providing related and an analysis of the Contraction of the



After entering the shopping cart, you are able to filter the available models, or just scroll down to view.







dol Sonto Fe - Blue

2011 Lincole MHX XWD - Black 2010 Audi A7 - Silve

#### **FILTERS:**

YEAR - will bring up all available models where the year range spans the selected year

MAKE - Will bring up all the models available for a given manufacturer.

**MODEL** - The filter is set for a "base" model. So, for instance, ATLAS will bring up all of the ATLAS and ATLAS CROSS models for Volkswagen, as well as any other manufacturers which have a model with ATLAS in the model name.

**STYLE** - This is meant as a generic classification - Car Truck / Utility / Van.

As of 4-20-2024 we have 33 models available for sale and download. We will be adding additional models weekly for the foreseeable future.

12 of the models we have already uploaded can be seen to the right.





2004 Hyundai Santa Fe - Blue

2011 Lincoln MKX AWD - Black \$100.00



2015-2018 2018 Audi A7 - Silver \$100.00



2016-2019 2018 Lincoln MKX - Gray \$100.00

2022 Toyota Corolla - White

\$100.00

2001-2008

5100.00



2018 Tesla Model S 100D - Blue \$100.00



2022 2022 Chevrolet 5500HD Chassis Cab-White \$100.00



2022-2023

2023 Chevrolet Bolt EUV - White

\$100.00



2021-2024 2023 Chevrolet Suburban - White \$100.00



2022-2023 2023 Chevrolet Traverse - White \$100.00



2023 Genesis GV70 - Silver \$100.00



2022-2024 2023 Honda Civic type R Sedan - White \$100.00

# iPhone and iPad LiDAR Scanner for Evidence Documentation

Presented by Robert Wyman

Wyman Enterprises, Inc. 786-246-8100



# SYMPOSIUM ON TRAFFIC SAFETY



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All items discussed reflect my personal research, and all items demonstrated have been purchased without any discounts or preferential agreements.





### **UPDATED THEME FOR THIS PRESENTATION**

Due to the rapidly-growing interest and acceptance of the iPhone/iPad LiDAR scanner over the last year, in the Traffic Crash Reconstruction industry, this presentation will now emphasize real-world LiDAR utilization instead of providing a more basic introduction to the technology.

As such, this presentation may encompass a shorter presentation time than allocated in the schedule.



Symposium on Traffic Safety



### **UPDATED THEME FOR THIS PRESENTATION**

Interestingly, the Crime Scene Investigation industry is still evaluating this technology, and still worried about the (non-existent) circumstance of having cellphones "inspected" by Criminal Defense Attorneys.

We can discuss why this issue is unfounded ... for CSI's as well as Crash Reconstructionists ... if you are interested, just let me know.







## This audience, regarding iPhone/iPad LiDAR:

(time to raise your hands, since everyone LOVES to participate 🙋 🙆)

- How many currently use LiDAR?
- How many do not use, but are familiar with the LiDAR features?
- How many think LiDAR is a simple cellphone novelty and not a useful tool?
- How many work for an agency not allowing cellphone use?



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## This audience, regarding iPhone/iPad LiDAR:

# Brief Scanning Demo (if everything works!)



Symposium on Traffic Safety



# Lidar

# **Light Detection and Ranging**

## Similar in scope to...

Radar ... Radio Detection and Ranging Sonar ... Sound Navigation and Ranging




# Lidar

Also called "laser imaging, detection, and ranging" or simply "3-D Laser Scanning"

### <u>Wikipedia</u>

"It is a method for determining ranges by targeting an object or a surface with a laser and measuring the time for the reflected light to return to the receiver"

Developed in 1961-1963, soon after development of the laser.





# Lidar

LiDAR is now commonly used in...

- Surveying
- Archaeology
- Geology
- Forestry
- Airborne mapping topography
- Airborne mapping littoral
- Artificial Intelligence / Machine Vision
- Automated/Autonomous Vehicles





LiDAR consists of an "emitter" element that projects an infrared laser pattern onto a target surface.

The surface must be within a physical range consistent with the output power of the emitter.

A receiver element detects the reflected light and processes it to calculate and obtain the desired output.





## Emitter range...

- Higher power = longer range = greater cost
- Lower power = shorter range = lesser cost
- At present, the well-known brands of large laser scanners are still required for widearea and/or distant targets.





























# April Tags (Targets)



## **R3D TARGET KIT**

The Recon-3D target kit provides the user with a set of different sized AprilTags to use in their scanning workflow. A set of magnetic targets can be placed on vehicle bodies or metal door frames while the vinyl sticker targets are useful to affix to metal, plastic or wood surfaces.

Target Kit includes: 2 x 8" Magnets 2 x 6" Magnets 2 x 4" Magnets 2 x 6" Vinyl Stickers 2 x 3.5" Vinyl Stickers





Introduction LiDAR Hardware LiDAR Background

The iPhone and iPad LiDAR first appeared on iPhone/iPad "Pro" versions (Pro and Pro Max), beginning with the iPhone 12 in 2020.

App development followed, with mostly novelty Apps appearing in the App Store by 2021, and more useful Apps appearing in 2022.





Initial Apps, and many current Apps, are architectural in nature... geared toward interior home and room measurements.

The first "forensic" App was **Recon-3D** by Eugene Liscio, P.E., released in 2022, after an extensive beta-test period.

Scanning technology continues to evolve, with photogrammetry, GPS, and other features being integrated with lasers.





Recon-3D continues to evolve as well, and is currently enjoying widespread testing, evaluation and real-world academic and casework use in the Recon field.

For example, Daniel Vomhof, a crash test team member at this conference, has already scanned an estimated 400 hundred vehicles with Recon-3D at crash-testing conferences around the country over the last year.





Discussions about 3-D scanners in cellphones began over a decade ago.

Apple, Samsung, Microsoft, Google and others received many "new feature wanted" recommendations for a scanner ... but NOT for practical consumer or professional use.

Instead, recommendations were for integration with GAMES, so kids could scan their own environments and create personalized gaming architecture.





If anyone in today's audience was an attendee at my "iPhone Apps for Crash Reconstruction" conference presentations for IPTM many years ago ...

... you heard me predict that future crash and crime scene investigations will have a phone or similar device capable of high-resolution scene photos, videos, and 3-D scene documentation/measurements.

Back then, this was dismissed as a toy or novelty feature, not a viable professional tool.





Regarding having a scanner as an input source for kid's games, the increase in school shootings and other juvenile crimes resulted in a marketing shift by the various phone and software companies.

No one wanted a headline reading something like, "School Shooter Planned Escape Route by Scanning Floorplan with iPhone App."

Thus, the scanner feature emphasis shifted to consumer and possible professional use.





Introduction LiDAR Hardware LiDAR Background Sample Apps

## **Apple App Store Sample Titles**

**3D LiDAR Scanner 3D Scanner App** CamToPlan – 3D Scanner & LiDAR **Canvas: LiDAR 3D Measurements** Dot3D – LiDAR 3D Scanning Magicplan MagiScan – AI 3D Scanner app Metascan – 3D Scanner Modelar – 3D LiDAR scanner Pix4Dcatch: 3D scanner







Introduction LiDAR Hardware LiDAR Background Sample Apps

## **Apple App Store Sample Titles**

Polycam 3D Scanner **Qlone 3D Scanner** RealScan – 3D Room Design Recon-3D **RENDR:** Floor plans in seconds **RoomScan Pro LiDAR floor plans** Scandy Pro: 3D Scanner, 3D App Scaniverse – 3D Scanner ScanKit SiteScape – LiDAR 3D Scanner





## Andrew S. Rich, BSME, ACTAR, ASE Rich Consulting, LLC

					Recon3D	Recond					Recon3D	Recon 3D
	<b>Total Station</b>	Wheel	<b>RC Ortho</b>	RTK	w/	3D NO		Wheel	<b>RC Ortho</b>	RTK	NO	with
					Targets	Targets					Targets	Targets
50	49.96	50.375	49.927	49.91	50.22	49.74		0.41	-0.03	-0.05	-0.22	0.26
100	99.95	100.71	99.966	99.95	100.17	99.47		0.76	0.02	0	-0.48	0.22
150	149.96	151.16	150.04	149.97	150	149.19		1.20	0.08	0.01	-0.77	0.04
200	199.92	201.375	200.012	199.94	199.91	198.95		1.46	0.09	0.02	-0.97	-0.01
GCP1 to GCP2	76.6	N/A	76.565	76.47				N/A	-0.03	-0.13		
GCP1 to GCP3	125.94	N/A	125.951	125.93		125.47		N/A	0.01	-0.01	-0.47	
GCP1 to GCP4	228.57	N/A	228.578	228.54	228.39	227.34		N/A	0.01	-0.03	-1.23	-0.18
T1 to T2	201.779	N/A	201.956	N/A	201.8	200.82		N/A	0.18	N/A	-0.959	0.021
							<b>RMS Error</b>	1.04 ft	0.08 ft	0.05 ft	0.80 ft	0.16 ft
							34					





## Andrew S. Rich, BSME, ACTAR, ASE Rich Consulting, LLC









Using the iPhone's LiDAR technology to capture 3D forensic data at crime and crash scenes

Sören Kottner<sup>a,\*</sup>, Michael J. Thali<sup>a</sup>, Dominic Gascho<sup>a</sup>

<sup>a</sup> Zurich Institute of Forensic Medicine, University of Zurich, Winterthurerstrasse 190/52, 8057 Zurich, Switzerland

#### ARTICLE INFO

ABSTRACT

Keywords:	Background: Three dimensional (3D) documentation of crime and crash scenes is common practice during
Keywords: Recon-3D Forensic imaging Forensic documentation 3D scanning 3D imaging 3D documentation Photogrammetry Smartphone Tablet Time of flight	<ul> <li>Background: Three-dimensional (3D) documentation of crime and crash scenes is common practice during forensic and medicolegal investigations. Such documentation at a scene is usually carried out by specially trained personnel using various 3D imaging devices and methods, such as terrestrial laser scanners. Unfortunately, this causes the implementation of 3D documentation at the scenes to be expensive and not readily accessible. In 2020, Apple introduced a light detection and ranging (LiDAR) sensor into their high-end mobile devices. In 2022, Recon-3D, an iOS application (app), was launched. This app turns an iPhone or iPad into a 3D scanner and is specifically targeted at crime and crash scene applications.</li> <li>Objectives: The aim of this study was to test the Recon-3D app based on exemplary scenarios to see whether this technology is generally applicable to document crime or crash scenes.</li> <li>Materials and Methods: An iPhone 13 Pro in combination with the Recon-3D app was used to document two indoor scenarios, a mock-up crime scene and a garage, as well as an outdoor scenario of a parked car. Each scenario was documented multiple times.</li> <li>Results: On average, data acquisition for one scene took less than 2 min. Known distances within the scenes were measured with a mean absolute error of 0.22 cm and a standard deviation of 0.18 cm.</li> <li>Conclusion: The imaging workflow was simple and quick, enabling any person to perform 3D documentation at a crime or crash scene. Overall, Recon-3D app appeared to be a useful application for forensic investigators.</li> </ul>

Check for updates





### ABSTRACT

*Background:* Three-dimensional (3D) documentation of crime and crash scenes is common practice during forensic and medicolegal investigations. Such documentation at a scene is usually carried out by specially trained personnel using various 3D imaging devices and methods, such as terrestrial laser scanners. Unfortunately, this causes the implementation of 3D documentation at the scenes to be expensive and not readily accessible. In 2020, Apple introduced a light detection and ranging (LiDAR) sensor into their high-end mobile devices. In 2022, Recon-3D, an iOS application (app), was launched. This app turns an iPhone or iPad into a 3D scanner and is specifically targeted at crime and crash scene applications.

*Objectives:* The aim of this study was to test the Recon-3D app based on exemplary scenarios to see whether this technology is generally applicable to document crime or crash scenes.

*Materials and Methods*: An iPhone 13 Pro in combination with the Recon-3D app was used to document two indoor scenarios, a mock-up crime scene and a garage, as well as an outdoor scenario of a parked car. Each scenario was documented multiple times.

*Results*: On average, data acquisition for one scene took less than 2 min. Known distances within the scenes were measured with a mean absolute error of 0.22 cm and a standard deviation of 0.18 cm.

*Conclusion:* The imaging workflow was simple and quick, enabling any person to perform 3D documentation at a crime or crash scene. Overall, Recon-3D appeared to be a useful application for forensic investigators.



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	2023-01-0614 Published 11 Apr 2023							
INTERNATIONAL®	Accuracy and Repeatability of Mobile Phone LiDAR Capture							
	Seth Higgins Miller, Alireza Hashemian, Robert Gillihan, and Saylor Benes J.S. Held LLC							
	<i>Citation:</i> Miller, S.H., Hashemian, A., Gillihan, R., and Benes, S., "Accuracy and Repeatability of Mobile Phone LiDAR Capture," SAE Technical Paper 2023-01-0614, 2023, doi:10.4271/2023-01-0614.							
Received: 01 Nov 2022	Revised: 09 Jan 2023 Accepted: 31 Jan 2023							





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### Recon-3D Measurement Accuracy Study for Small Scenes

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#### ABSTRACT

Recon-3D is an iOS mobile application dedicated to crash and crime scene documentation of small scenes, which fuses the Light Detection and Ranging (LiDAR) sensor and video frames to reconstruct 3D geometry as point clouds. In a recent training course, sixty students were asked to set up a mock scene with numbered measurement markers, scan the scene with their mobile devices, and provide 10 measurements between the numbered measurement markers in their scenes (n = 600). The results of these measurements were compiled and tabulated for accuracy. The average error of all participants was found to be approximately –2 mm with a standard deviation of 15 mm. The mean absolute error was found to be approximately 1 cm and the maximum error for any one participant was 10 cm. Expressing the errors in terms of percent, the average error for all participants was approximately –0.078% with a maximum percent error of 2.83%. Although these measurement exercises were uncontrolled, they show that the majority of errors (2 $\sigma$ ), fell within 3 cm. Future studies using point-to-point measurements should include repeatability tests in a controlled environment as there were several variables which were unaccounted for in this study.

Keywords: LiDAR, crime scene investigation, crime scene reconstruction, forensic science

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#### Introduction

Crime and crash scene documentation has benefited greatly by the use of total stations, terrestrial LiDAR scanners (TLS), and the use of photogrammetry. These technologies offer ways of documenting scenes in a highly detailed and efficient manner. Past studies have focused on LiDAR technology and photogrammetry in applications such as collision reconstruction, rime scene documentation, bloodstain pattern analysis, and bullet trajectory analysis. There has been great acceptance of the TLS and photogrammetry in the forensic field, especially the use of aerial imagery from drones in crash scene scenarios. These technologies all have their individual limitations whether it be cost, maintenance, portability, required level of training, or flexibility. Usually, the technology is available to a dedicated group of individuals who have access to the equipment and have been properly certified and trained.

One of the most limiting factors for smaller companies and police agencies is cost. Many investigators and private forensic engineering firms have been searching for low-cost tools which can provide 3D documentation capability within a reasonable margin of error and accuracy. In this regard, photogrammetry is a strong contender since it requires the use of



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FIGURE 3: AprilTag used in Recon-3D.

AprilTags which have been placed in the scene. As a best practice, the larger the spacing between the AprilTags, the improved error reduction. Once the data is finished processing, the distance between AprilTags is automatically adjusted for scale based on the user's input reference distance. In cases where a reference distance is not available, the scaling of the object is approximated by the distance measurements recorded with the LiDAR sensor, where the accuracy and repeatability are not defined.

#### Method

In June 2022, a Recon-3D training class was held through an online platform and students

were given instruction on how the LiDAR sensor works, the use of the app, settings, scanning in varying situations, and how to take measurements using CloudCompare software. Students were also required to complete an assignment as part of the class certification with instructions as follows:

- 1. Choose an indoor or outdoor area to scan using Recon-3D.
- 2. Place 10 numbered measurement markers (provided in a PDF and printed on paper) throughout the scene in random positions to include horizontal and vertical measurements. Markers were to be secured using tape or placed on a surface where they would not move during the measurement exercise. Example layout of targets shown in Figure 4.
- 3. Place two AprilTags in the scene as far apart as possible.
- Manually measure the distance between the two AprilTags and 10 of the measurement markers with a tape measure (or other instrument).
- 5. Using Recon-3D, create a new scan and use at least a 5 mm resolution.
- Enter the reference distance between the two AprilTags.
- 7. Process the data on the cloud.
- 8. Once data is processed, download the data, and import into CloudCompare.
- 9. In CloudCompare, record measurements between the previously manually measured



FIGURE 4: Recon-3D data in CloudCompare software showing an example scene with measurement markers and AprilTags.











Absolute Error (mm) Distribution, n=600





Absolute Percentage Error (%) Distribution, n=600



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# Other New Products of Interest Moasure One







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# Other New Products of Interest Moasure One



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# Other New Products of Interest Moasure One

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View the distance, gradient, or rise and fall – or simply tap any point on the measurement drawing to view the recorded X, Y, & Z coordinate data.

You can now rapidly and accurately map a job site – complete with area, perimeter and elevation in the time it takes to walk around.







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# Other New Products of Interest Meazor 3D







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# Other New Products of Interest Matterport







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# Other New Products of Interest Matterport

#### Simplicity through automation.

Cortex AI automates many steps in the model creation process, including blurring faces as needed, choosing the best images from your scans, creating accurate measurements, and identifying different objects.

Once you've finished scanning, Cortex AI allows you to sit back and wait for your completed 3D model to render.







Google Search Keywords for Additional Info, Articles and Tests

iPhone LiDAR
iPhone LiDAR Emitter
iPhone LiDAR Time of Flight
iPhone LiDAR vs. Total Station
iPhone LiDAR vs. Laser Scanner ["brand name"]
iPhone LiDAR vs. Photogrammetry
iPhone LiDAR 3D Scanning

... and similar sample combinations







## Sample YouTube Videos of Interest



## "What is LiDAR? (& Why is it on Apple Devices All of a Sudden)," from TheUnlockr



"Georeferencing iPhone 14 Pro LiDAR using Targets," from Rami Tamimi






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## Sample YouTube Videos of Interest



# "iPhone 14 Pro LIDAR vs. Survey Total Station Accuracy," from Rami Tamimi



## "Recon-3D New Version Webinar," from Eugene Liscio



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## Sample YouTube Videos of Interest



# "An interesting discovery using iPhone 12 LiDAR scanner," from Eugene Liscio



## "Laser Scanning vs. iPhone LiDAR," from Eugene Liscio



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#### **Sample Scans**

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## SAMPLE DATA











**Dodge Journey** Dodge Journey scan with 4m...

Hummer Courtesy of Jason Keller

Body CSI Dummy on tiled floor, 1mm..

**BMW Damaged** Courtesy of Joseph Catone

**Multiquip Tank** Multiquip tank scan 5mm...





Graffiti Belgium Courtesy of Jason Keller

Service House Scanned at 5mm resolution



GMC Plow 5mm resolution





**Concrete Pillars** Concrete pillars under bridge

CAT Equipmen Ω CAT Heavy Equipr



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LiDAR Hardware LiDAR Background Sample Apps **Measurement Studies** Phones with Other Devices **Further Research Conclusions and** Recommendations

The iPhone and iPad LiDAR features are tools and not toys. They add a new level of portability and always-available scanning functions to your workflow.

Accuracy and Precision are excellent if used with a purposeful scanning methodology.

**Reconstructionists should consider testing and** perhaps adopting these new technologies, as they can make evidence documentation, measurements and diagrams faster and easier than with other devices.



# COMPARISON OF RECON 3D TO CLOUD COMPARE: A BRIEF SUMMARY

PATRICK DAVIS





#### PROCEDURE

- Scans of the same subject were collected using Faro 3D Scanner and Recon 3D
- Both scans were brought into Cloud Compare
- The Recon3D scans were then aligned and scaled using the faro scan as the reference
- The cloud to cloud distance was then computed in cloud compare using the Faro scan as the reference



#### TEST I



- 569,720 points
- Recon 3D scan scaled by 1.008 to match Faro scan
- 50.5% of points within 0.2 inches of faro scan
- 35.5% between 0.2 and 0.624 inches
- Around 4.7% between 0.624 and 0.96 inches
- Around 10% between 0.96 and 3.6 inches. These are mainly associated with missing segments in the Faro scan



#### TEST 2



- 568,483 points
- Recon 3d scan scaled by 1.00279 to match Faro scan
- 78% within 0.2 inches
- 17% within between
  0.2 and 0.79 inches
- 5% greater than 0.79 inches. These points are mainly associated with missing segments in the Faro scan



#### TEST 3



- 965,986 points
- Recon 3D scan scaled by 1.0036 to match Faro scan
- 27.5% of points within 0.25 inches
- 37.4% between 0.25 inches and 0.72 inches
- 13.1% between 0.72 and 1.08 inches
- Around 20% greater than 1.08 inches. These points are mainly associated with missing segments in the Faro scan