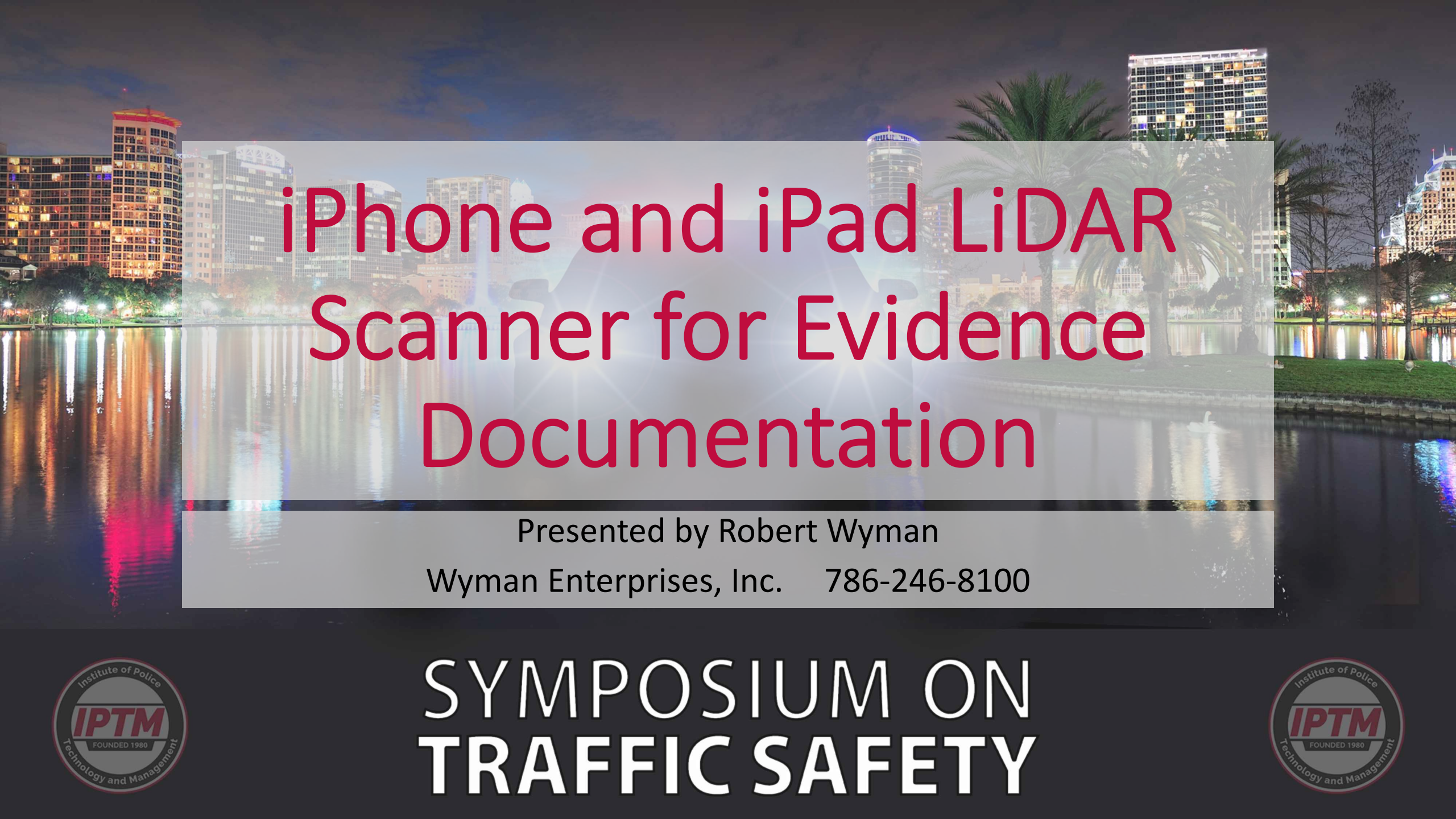

iPhone and iPad LiDAR Scanner for Evidence Documentation

Presented by Robert Wyman

Wyman Enterprises, Inc. 786-246-8100

SYMPOSIUM ON TRAFFIC SAFETY

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No hardware, software, or services mentioned in this presentation have been freely provided by the respective manufacturers, authors or service providers.

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.

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?

This audience, regarding iPhone/iPad LiDAR:

Brief Scanning Demo (if everything works!)

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**"

Wikipedia

"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…

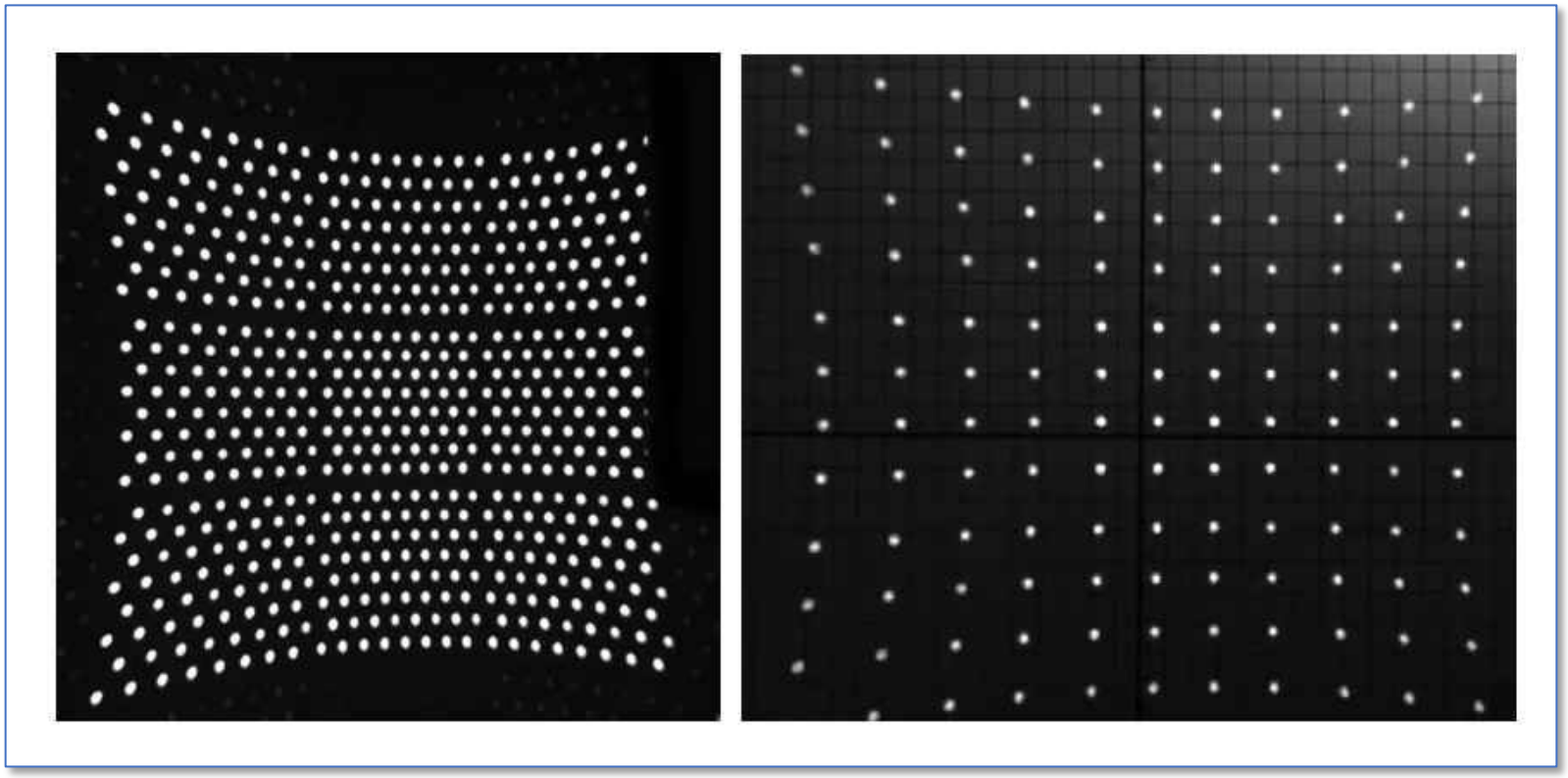
- Higher power = longer range = greater cost
- Lower power = shorter range = lesser cost

- At present, the well-known brands of large laser scanners are still required for wide-area and/or distant targets.

Introduction
LiDAR Hardware

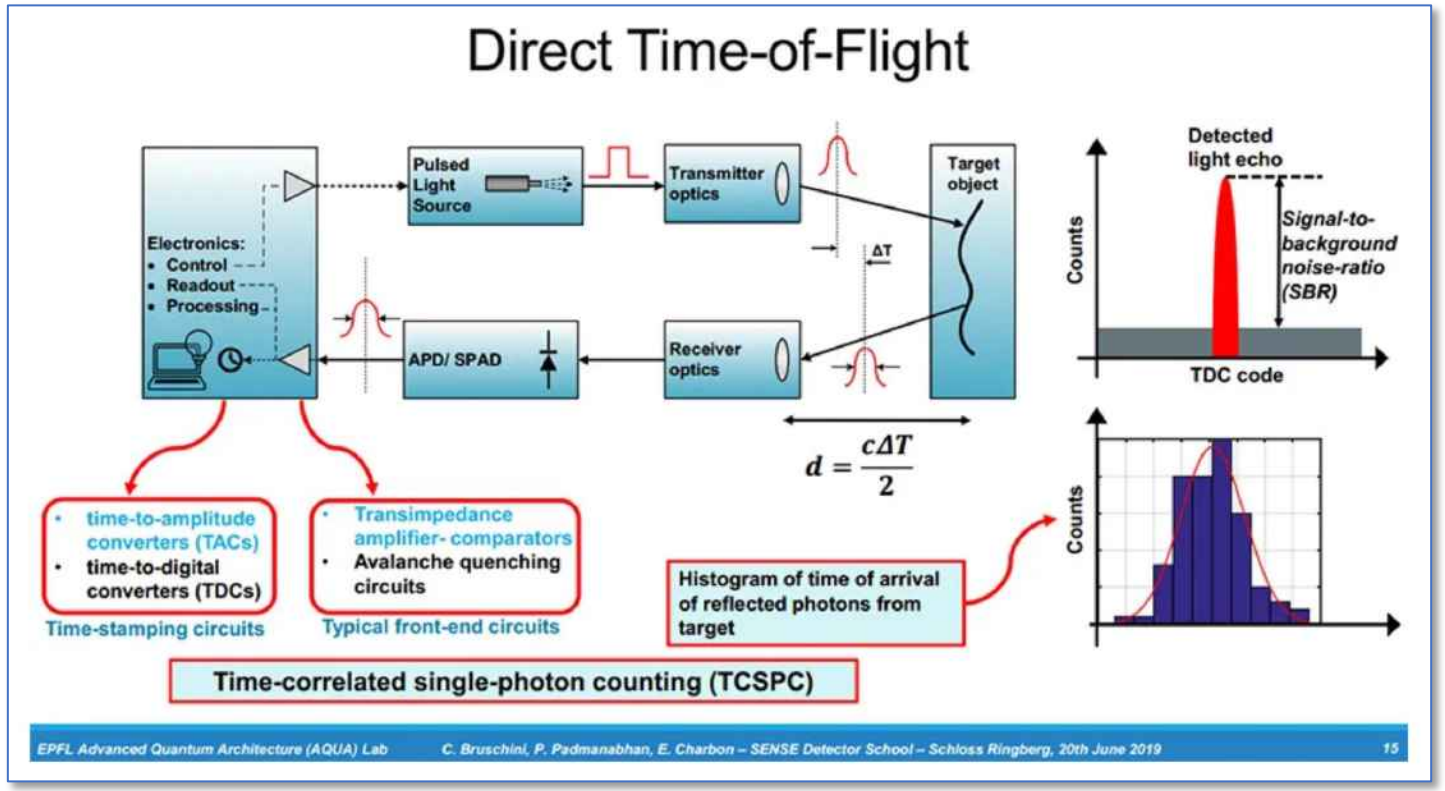
Note: Graphics obtained from various webpages reporting on this topic.

Introduction
LiDAR Hardware



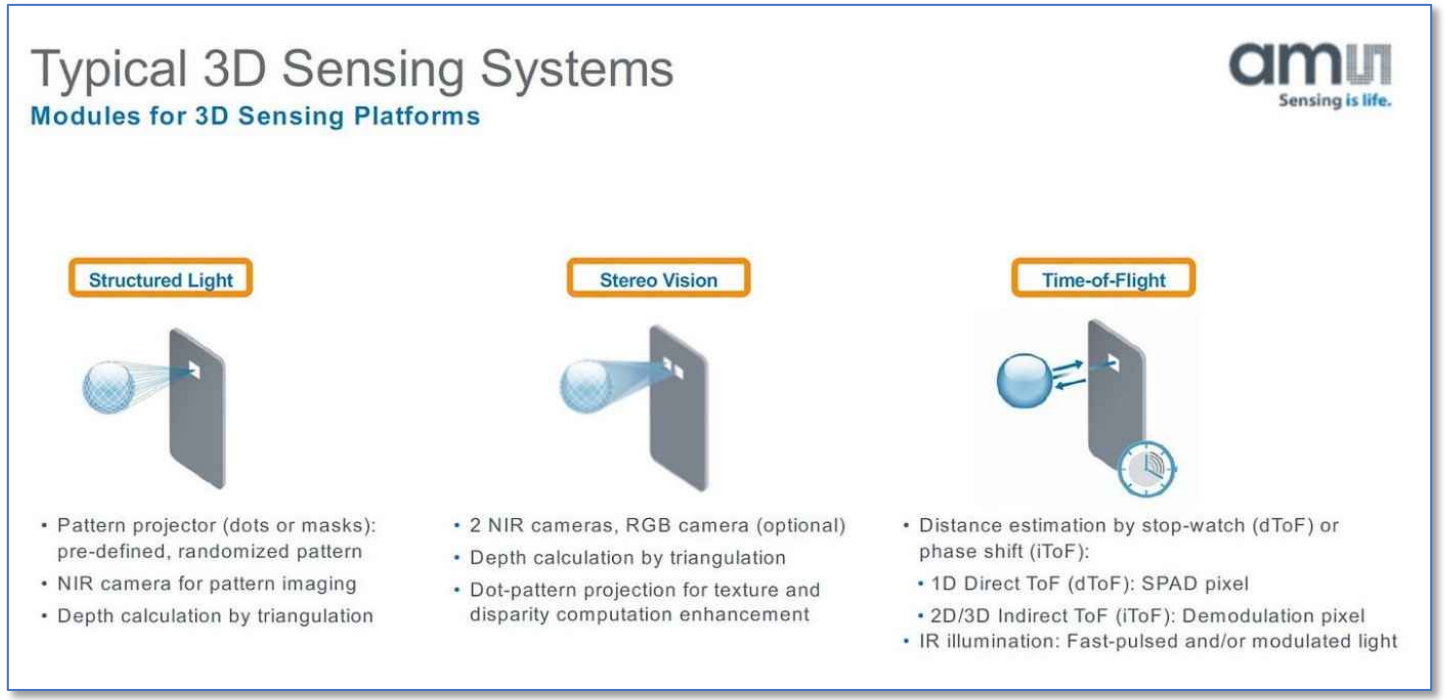
Note: Graphics obtained from various webpages reporting on this topic.

Introduction
LiDAR Hardware



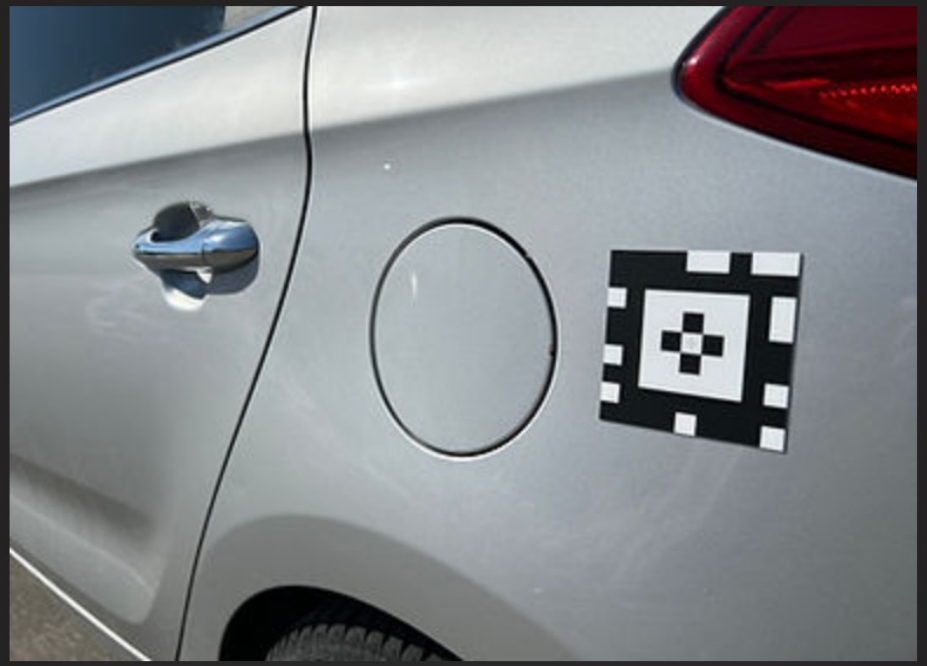
Note: Graphics obtained from various webpages reporting on this topic.

Introduction
LiDAR Hardware



Note: Graphics obtained from various webpages reporting on this topic.

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

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.

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

Apple App Store Sample Titles

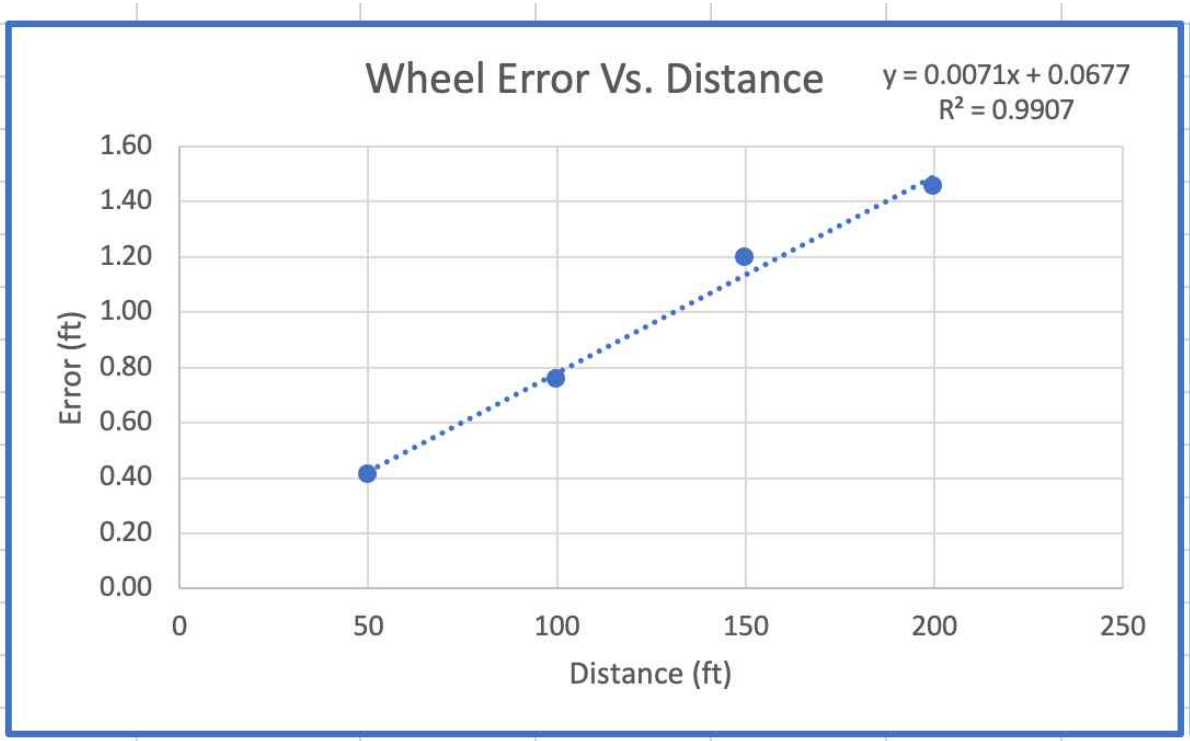
Polycam 3D Scanner
Qlone 3D Scanner
RealScan – 3D Room Design
Recon-3D
RENDR: Floor plans in seconds
RoomScan Pro LiDAR floor plans
Scandy Pro: 3D Scanner, 3D App
Scaniverse – 3D Scanner
ScanKit
SiteScape – LiDAR 3D Scanner

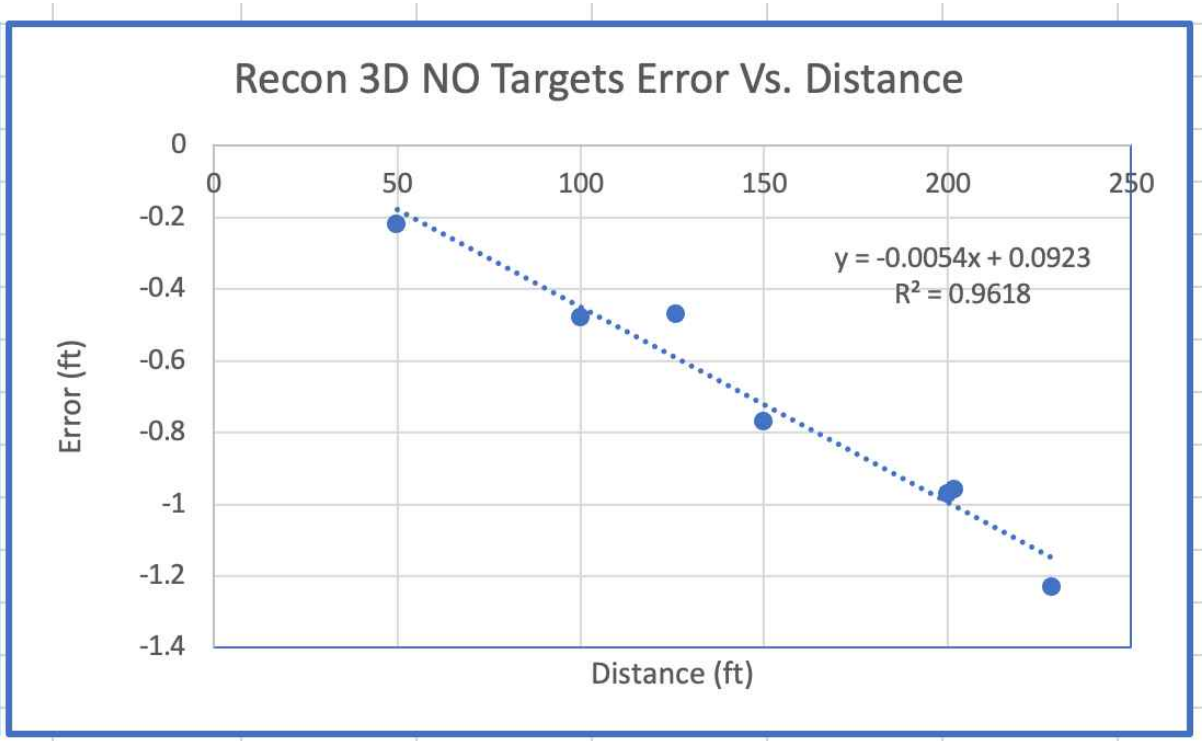
Andrew S. Rich, BSME, ACTAR, ASE
Rich Consulting, LLC

	Total Station	Wheel	RC Ortho	RTK	Recon3D w/ Targets	Recond 3D NO Targets
50	49.96	50.375	49.927	49.91	50.22	49.74
100	99.95	100.71	99.966	99.95	100.17	99.47
150	149.96	151.16	150.04	149.97	150	149.19
200	199.92	201.375	200.012	199.94	199.91	198.95
GCP1 to GCP2	76.6	N/A	76.565	76.47		
GCP1 to GCP3	125.94	N/A	125.951	125.93		125.47
GCP1 to GCP4	228.57	N/A	228.578	228.54	228.39	227.34
T1 to T2	201.779	N/A	201.956	N/A	201.8	200.82

	Wheel	RC Ortho	RTK	Recon3D NO Targets	Recon 3D with Targets
	0.41	-0.03	-0.05	-0.22	0.26
	0.76	0.02	0	-0.48	0.22
	1.20	0.08	0.01	-0.77	0.04
	1.46	0.09	0.02	-0.97	-0.01
	N/A	-0.03	-0.13		
	N/A	0.01	-0.01	-0.47	
	N/A	0.01	-0.03	-1.23	-0.18
	N/A	0.18	N/A	-0.959	0.021
RMS Error	1.04 ft	0.08 ft	0.05 ft	0.80 ft	0.16 ft

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





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Forensic Imaging 32 (2023) 200535

Contents lists available at ScienceDirect

Forensic Imaging

journal homepage: www.sciencedirect.com/journal/forensic-imaging

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

Sören Kottner [a,*], Michael J. Thali [a], Dominic Gascho [a]

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ARTICLE INFO

Keywords:
Recon-3D
Forensic imaging
Forensic documentation
3D scanning
3D imaging
3D documentation
Photogrammetry
Smartphone
Tablet
Time of flight

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.

A B S T R A C T

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Fig. 4. Screenshots of the 3D point cloud from the garage. Views of the scene from different angles are given in images a – c. The point size of the data points was increased to provide a better visualization of the data.

Fig. 5. Screenshots of the 3D point cloud from the parked car. Views of the car from different angles are given in images a – c. The license plate has been painted over to hide the original license plate number. The point size of the data points was increased to provide a better visualization of the data.

2023-01-0614 Published 11 Apr 2023

SAE INTERNATIONAL

Accuracy and Repeatability of Mobile Phone LiDAR Capture

Seth Higgins Miller, Alireza Hashemian, Robert Gillihan, and Saylor Benes J.S. Held LLC

Citation: 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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Original Article

Recon-3D Measurement Accuracy Study for Small Scenes

Eugene Liscio & Jihwa Lim
ai2-3D Forensics, Ontario, Canada

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 (2σ), 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

Article Information

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Published: 25 April 2023

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Author contact:
eliscio@ai2-3d.com

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, crime 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

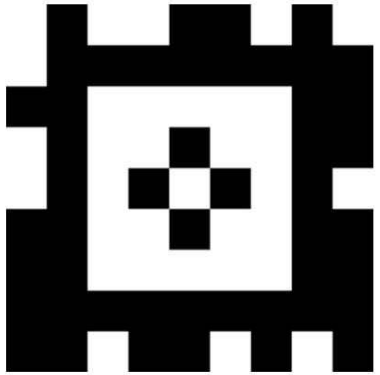

Figure 3: AprilTag used in Recon-3D.

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.
4. 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.
6. 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.

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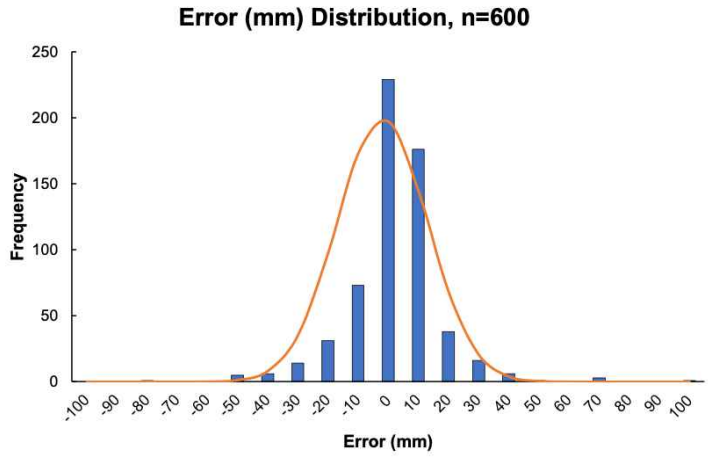

Figure 5: Histogram with a normal curve showing distribution of errors from student assignments, n = 600.

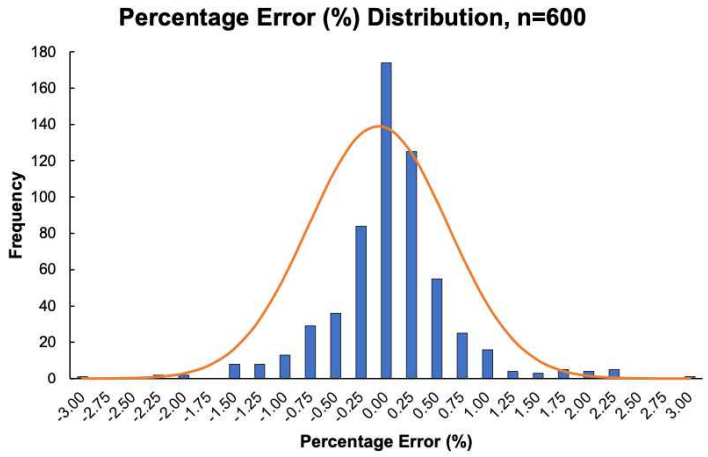

Figure 7: Histogram with a normal curve showing the percentage of error distribution, n = 600.

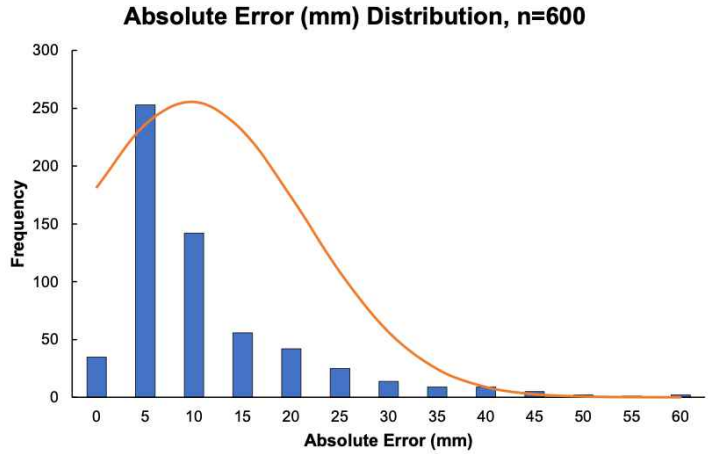

Figure 5: Histogram with a normal curve showing absolute errors which is a measure of the magnitude of errors n = 600.

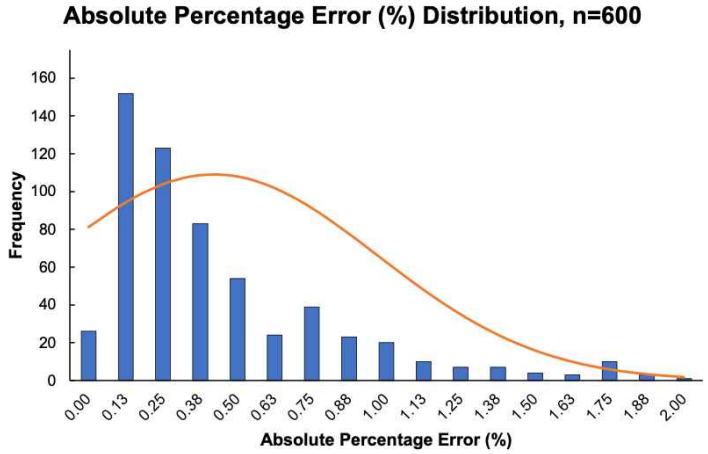

Figure 8: Histogram with a normal curve showing the absolute percentage error distribution, n = 600.

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Other New Products of Interest

Moasure One

moasure

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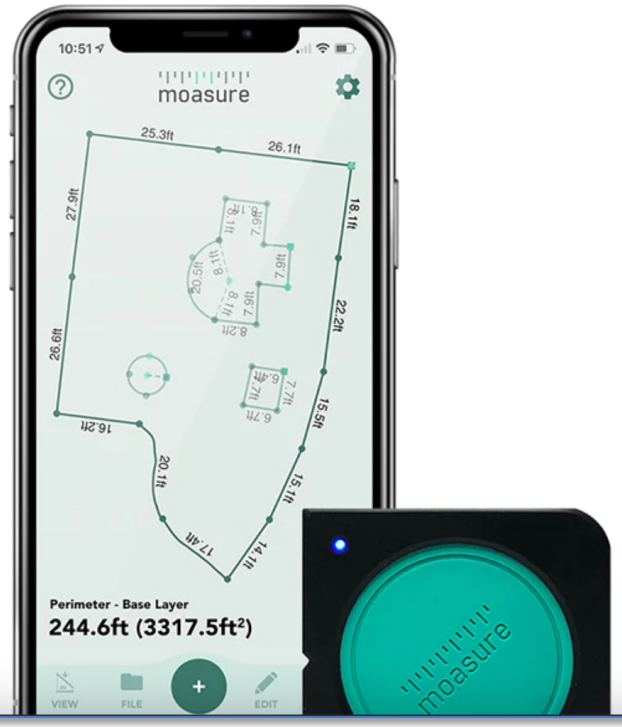

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$449.00 USD Our views on quality

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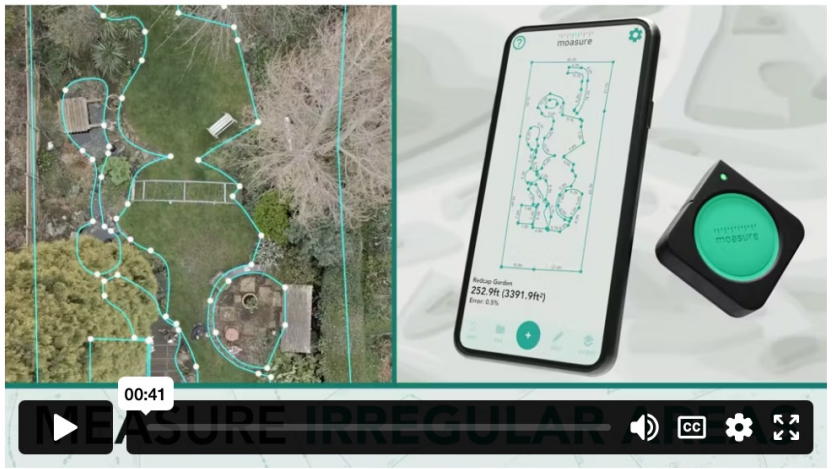
Moasure One



Measure & Draw Simultaneously

Effortlessly measure curves and free-form shapes. Simply trace along the edges of an area using Moasure ONE to digitally capture the shape and dimensions. Rapidly measure the perimeter and calculate the area of curved lawns, pools and other shapes and spaces – regular or irregular.

Is It Fast & Accurate?

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Moasure One

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As you measure, you'll see Moasure draw a complete 3D site model on your smartphone screen – in real time.

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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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Meazor 3D

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6-in-1 | 40m Multi-room Scan | Export to CAD | 3D Obstacle Avoidance | 2mm Precision | 3 Apps Integration

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Meazor 3D

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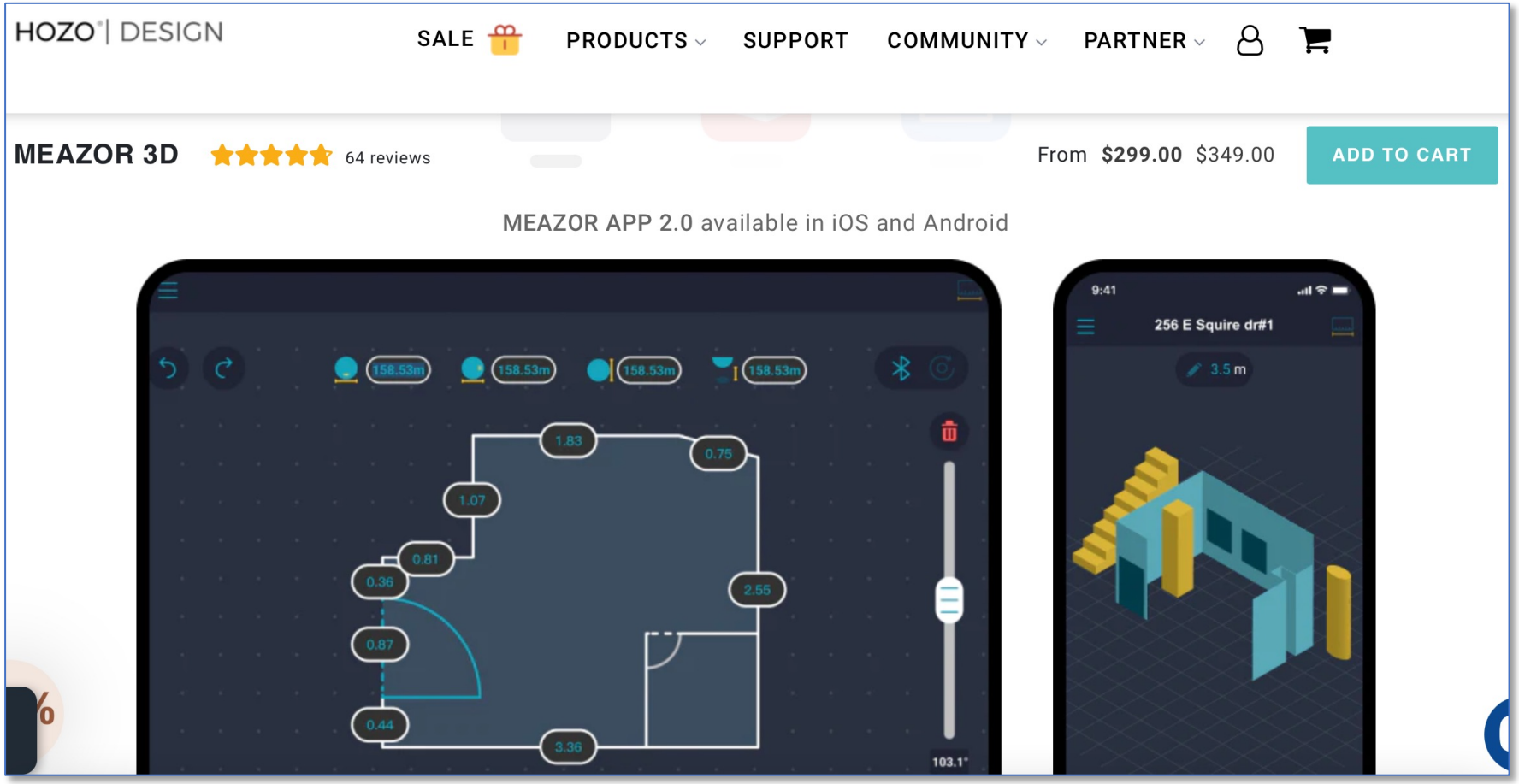
Meazor 3D



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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

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

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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- Conclusions and Recommendations

Sample Scans

HOME SUBSCRIBE TRAINING FAQ TUTORIALS ACCESSORIES SAMPLE DATA RESEARCH ABOUT CONTACT

SAMPLE DATA

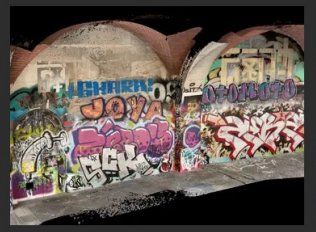
Dodge Journey
Dodge Journey scan with 4m…

Hummer
Courtesy of Jason Keller

Body CSI
Dummy on tiled floor, 1mm…

BMW Damaged
Courtesy of Joseph Catone

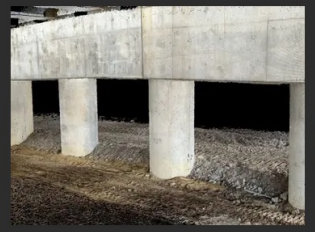
Multiquip Tank
Multiquip tank scan 5mm…



Graffiti Belgium
Courtesy of Jason Keller

Service House
Scanned at 5mm resolution

GMC Plow
5mm resolution



Concrete Pillars
Concrete pillars under bridge

CAT Equipmer
CAT Heavy Equipm

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.