

# Automated 3D Scanning System for Small Part Digital Twins

**Michael Raphael**  
President

DIRECT DIMENSIONS 

**RAMP MD**

**DIGITAL  
MANUFACTURING**

BUILDING A RESILIENT SUPPLY CHAIN

# Automated 3D Scanning System for Small Part Digital Twins

- Who is Direct Dimensions?
- 3D Scanning Tools and Options
- Automation
- Using Dense Photogrammetry for AM Part Inspection
- Examples
- Summary and Questions

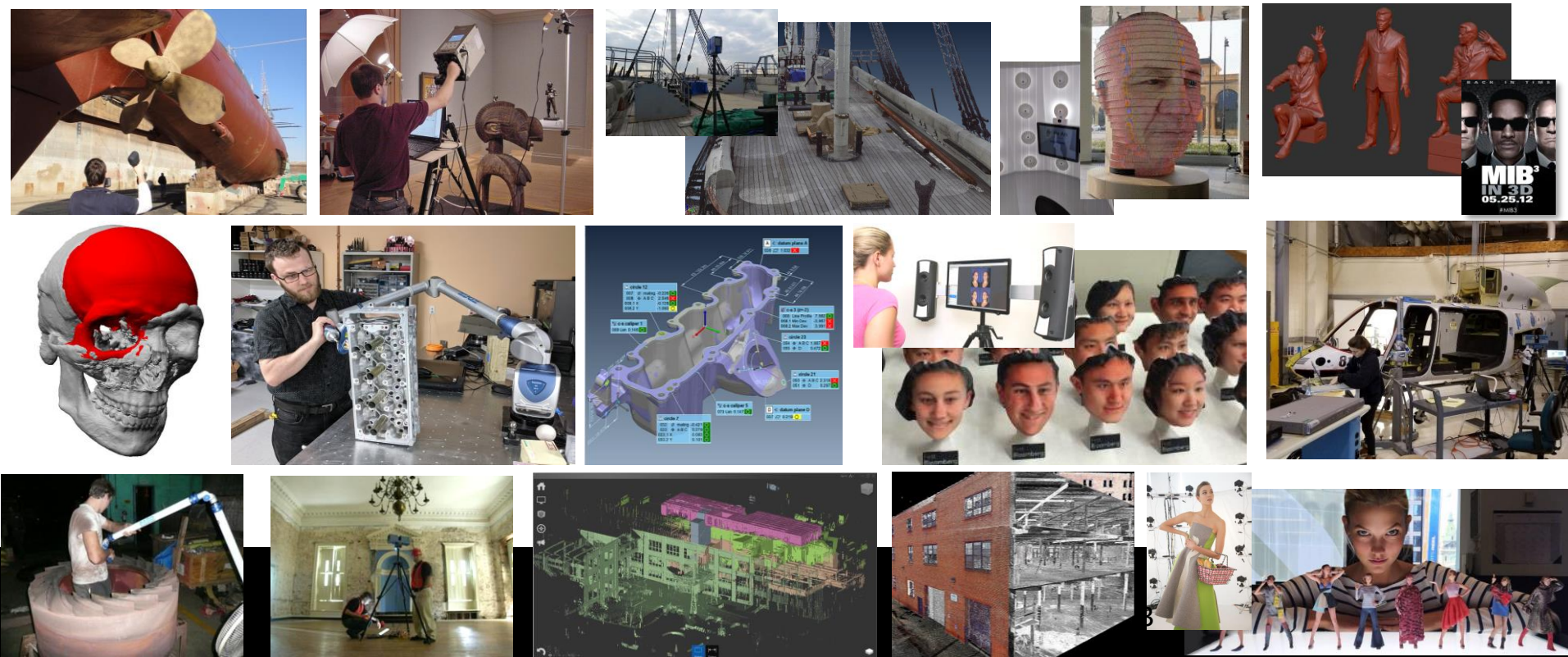


Outline

DIRECT DIMENSIONS  
Rapid Solutions to 3D Problems

**Direct Dimensions** was founded in 1995 to provide 3D solutions to the aerospace industry. We provide 3D scanning services, equipment sales, and custom solution development.

We have completed 1000's projects for clients in manufacturing, consumer products, architecture, medicine, entertainment, historic preservation, defense, and the arts.



## Background

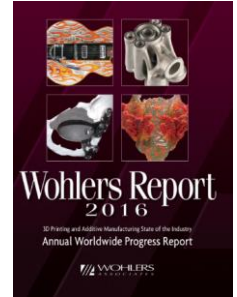
Engineering undergrad from Va Tech  
Masters of Engineering Admin, GW  
10 years in aerospace engr & mfg at LMT  
Co-developed the FaroArm PCMM

## Direct Dimensions

Founded in 1995 with a FaroArm  
'One-Stop' 3D scanning shop  
Staff of 25+, we just turned 28 yrs old!

## Professional Life

Author for LiDAR News  
Contributor to Wohler's Report  
Active with many 3D conferences  
Keynoted at CMSC Conference on Future of 3D Scanning



# Founder Biography

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# Visions made real with technology

By GEORGE ROACHE  
Daily Times and Union

SALISBURY — Lee Newcomb sees wire conveyor belt manufacturer Cambridge Inc. expanding into the Eastern markets.

But to do so, said the 40-year-old Cambridge firm's production manager, the company needs ways to help lower costs and improve quality to stay ahead of the competition.

"This is a very competitive business, and we see improvements in technology as making us more cost-effective," he said, walking through the exhibits at the Mid-Atlantic Technology Expo held at Salisbury State University Wednesday.

Newcomb said he was especially interested in finding an information retrieval system he could use to link his shop's electronic computers electronically with customer order files. That would be more effi-



Photo by Lee Barker

Michael Rayhead of Direct Dimensions Inc. in Baltimore demonstrates the use of a portable coordinate measuring machine which can be used to solve a variety of manufacturing problems on location. The demonstration was held Wednesday at the Mid-Atlantic Technology Expo.

Newcomb was not alone in taking advantage of the opportunity to fulfill a vision of staying ahead of the pack.

of the road." Having the proper data collection systems on the shop floor will let his production managers decrease the time it takes to manufacture products, lower raw materials inventory costs by not ordering components from vendors until they really need them and keep their customers happy by being able to tell them exactly when their orders will be finished, Corson said.

"If manufacturers can reduce their process time, they'll be able to generate more value, there's no question about that," said by creating more jobs," said Newater, operations director Michael W. Puls.

Bruce Leiner wants sales information that will tell him what customers who shop at his Candy Kitchen Shoppes Inc. stores like most or least, or when his cooks have messed up a batch of candy.

"Each batch is handmade," he

Direct Dimensions was founded in 1995 to provide 3D solutions to the aerospace industry. Since then, we have expanded to over 25 employees and have completed over 1000's projects for industrial, architectural, medical, movie, historic preservation, consumer product, and art clients.



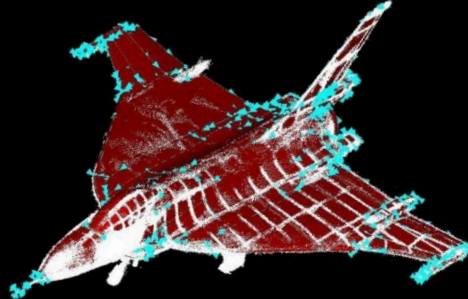
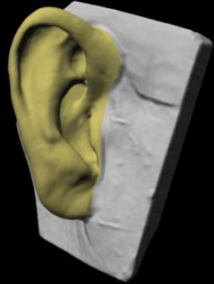
# History

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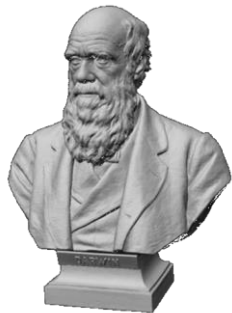
Direct Dimensions is dedicated to tackling the most difficult 3D scanning challenges with the most advanced 3D technologies available.

We have the right tools and experienced staff to provide optimized solutions for any industry, application, or size - from microns to meters.



Mission

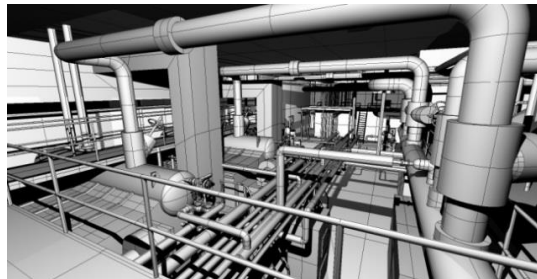
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**Art/Sculpture/  
Museum**



**Movie/Film/TV**



**Building & Facilities**

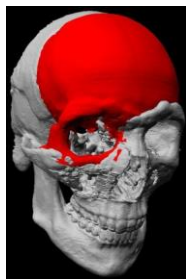


**Aerospace**



**Military/Defense**

Direct Dimensions operates across virtually all applications for 3D scanning.



**Medical**



**Archaeology  
& Historic**



**Industrial & Mfg**



**Consumer Products**



**Industries and Markets**

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Our scanning technicians have worked in every environment imaginable using the widest variety of scanning and digitizing platforms available.  
*All are direct employees of Direct Dimensions.*

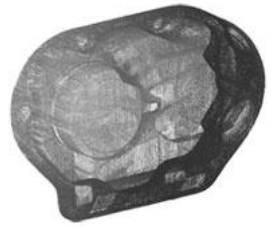


# Experienced Technical Staff

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# Reverse Engineering

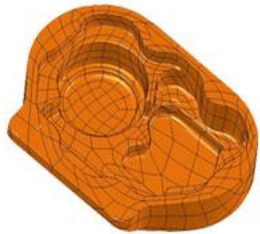
Point Cloud



Polygon Mesh



Rapid NURBS



Hybrid Model

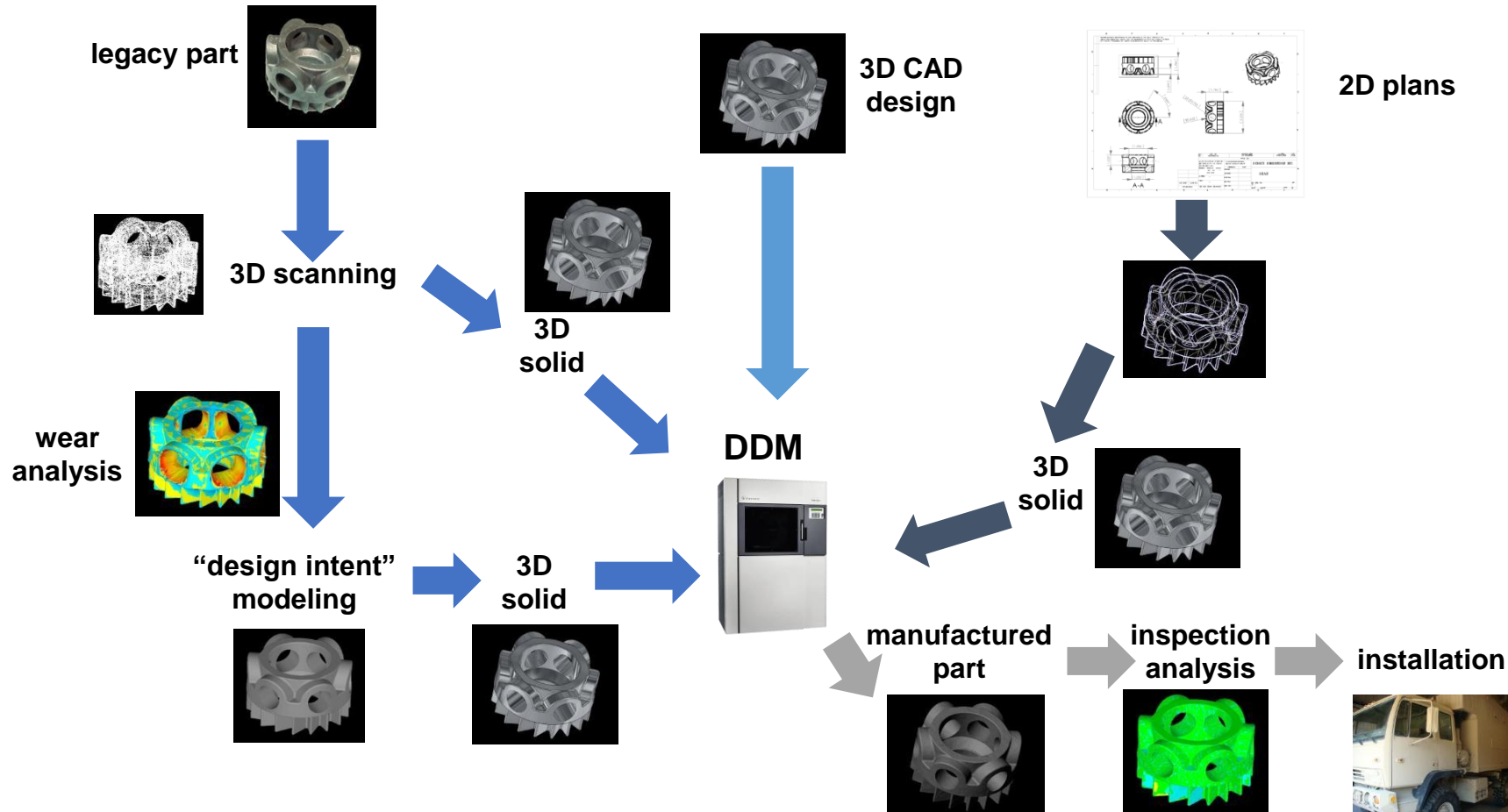


Engineered Solid Model



Engineered Surface Model





# Direct Digital Mfg Workflow (DDM)

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# Scanner Technologies

## Accuracy and Field of View

Inspection



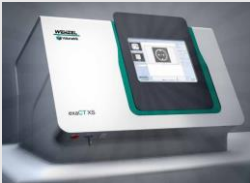
Structured light

Automatable



Arm

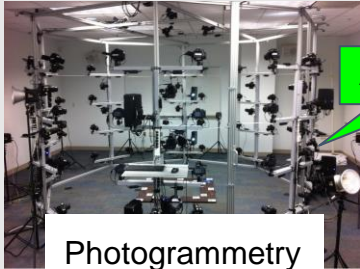
Reverse-engineering



X-Ray



Handheld



Photogrammetry

Automatable



LIDAR

↑ Accuracy



Handheld



Visualization



Object size →



What's the best scanner for the job?

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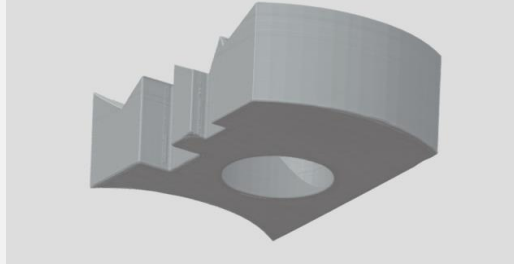
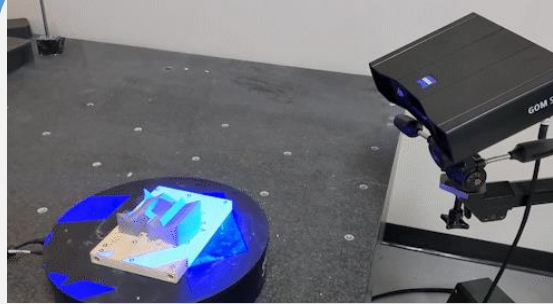
Industrial parts typically require surfaces inspected within the range of +/- 76 microns (+/- 0.003")

### Arm



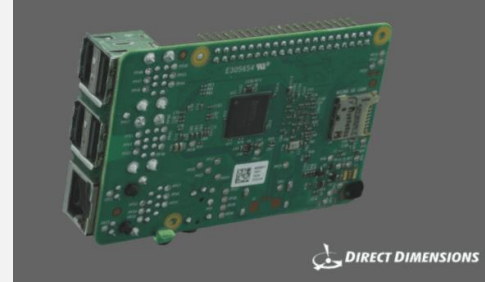
- Excellent accuracy and resolution.
- No warm-up time.
- Easy to calibrate.
- Manual scanning, but easier to use when faced with a variety of parts to scan.

### Structured light



- **Excellent accuracy and resolution.**
- **Can be automated for repeated inspection of similar parts.**

### Dense Photogrammetry



- Automatable.
- Scalable.
- Excellent color.
- Sufficient accuracy and resolution for many inspection applications.

Device	Size range	Automatable	Accurate enough for visualization	Accurate enough for reverse engineering	Cost
<b>Structured light Scanner</b>	Different systems capable of millimeters to few meter	Yes by attaching to a robot	No color	Yes	Highest
<b>Arm with Scanner</b>	Millimeters to few meters	No, completely manual	Limited models with color	Yes	Medium
<b>Handhead Scanner</b>	Centimeters to Meters	Possible but not practical	Yes	Medium accuracy	Low
<b>Spherical Scanner</b>	Meters to half a kilometer	Possible	Yes	Yes	Medium
<b>Photogrammetry</b>	<b>Different lenses capable of millimeters to meters</b>	<b>Yes</b>	<b>Yes - with excellent color</b>	<b>Medium accuracy</b>	<b>High, but very scalable and flexible</b>



# What's the best scanning technology?

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# What is Dense Photogrammetry?

Dense Photogrammetry creates 3D models from 2D images and software

Step 1: Find common, “interesting” pixel clusters (tie-points) in overlapping photos, then triangulate to determine the locations of the cameras and points.

*Sparse target-based photogrammetry uses this technique to make high-accuracy point-to-point measurements.*

Step 2: Use the camera locations and tie-points to fill in the object’s surface, pixel by pixel.

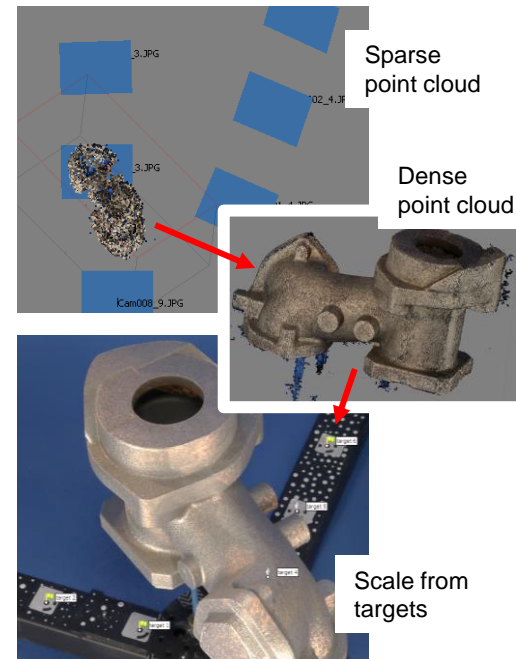
Step 3: Use a known scale reference in the images to scale the entire model.

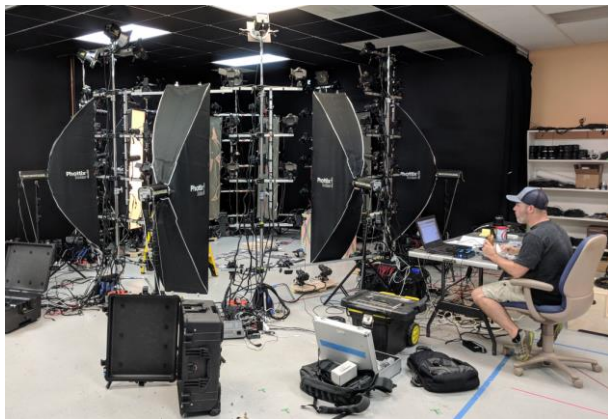
## Advantages:

- Consumer cameras are the cheapest source of high-quality pixels.
- The camera needs precision, but the scanner structure does not.
- "Do-it-yourself-ness" makes it easy to customize to a particular scale and workflow – endless lenses and camera automation tools are available.
- COTS software enables automatic processing.
- DSLR cameras produce fabulous color.
- Inexpensive.

## Challenges:

- It's a computer-intensive process.
- Parts with plain-colored surfaces lack tie points.
- It needs lots of pictures.
- Scanning time is decreased by increasing the number of cameras.





DDI built a 128-camera photogrammetry rig used to capture actors for VFX. The latest incarnation includes polarized lights for capturing shiny surfaces, and wheeled, telescoping camera towers for quick set-up. This system has been used for movies such as Avengers Infinity Wars and Avengers Endgame, and a photoshoot of super-model Karlie Kloss in Vogue.

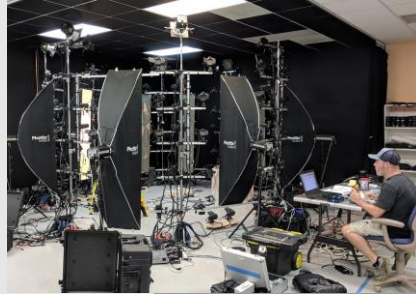


# Feasibility – Quality and Portability

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More Special Purpose →

↑  
More  
Automation

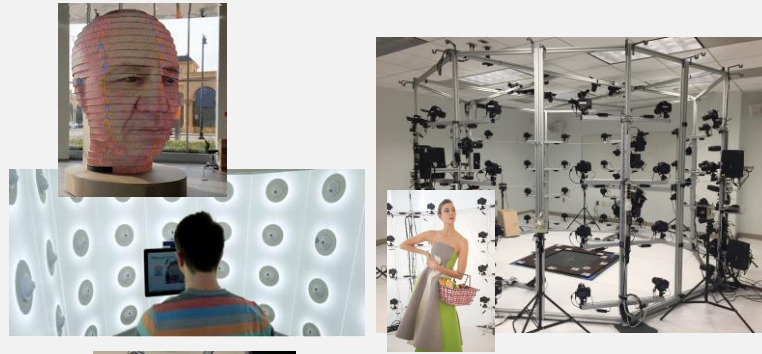


# Photogrammetry Camera Rigs

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*Moving Subjects*

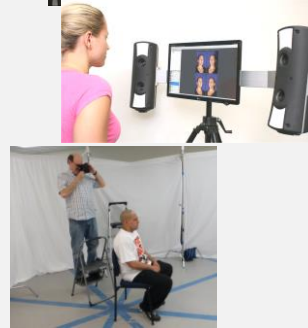
# Scalability of Photogrammetry Systems



**Number of cameras**



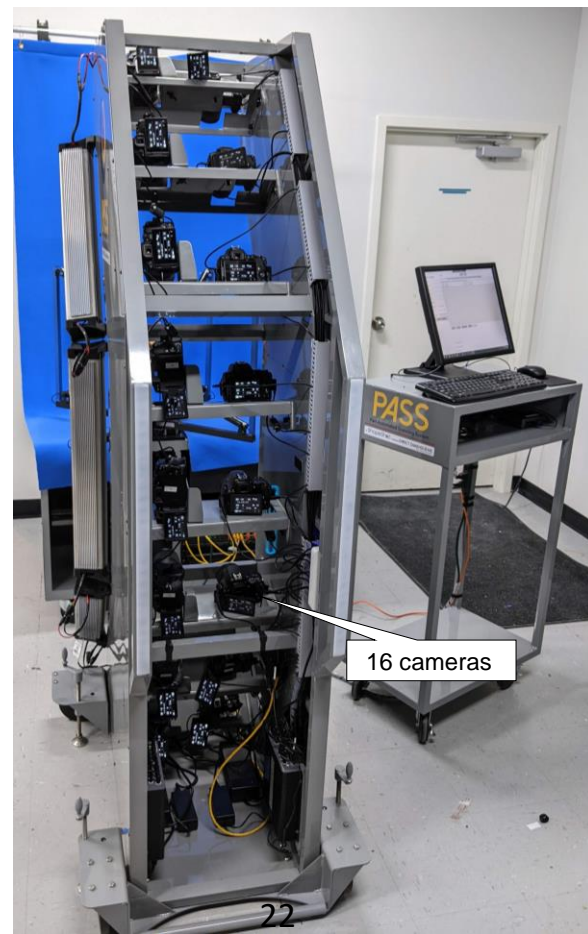
*Stationary Subjects*



**Object size**

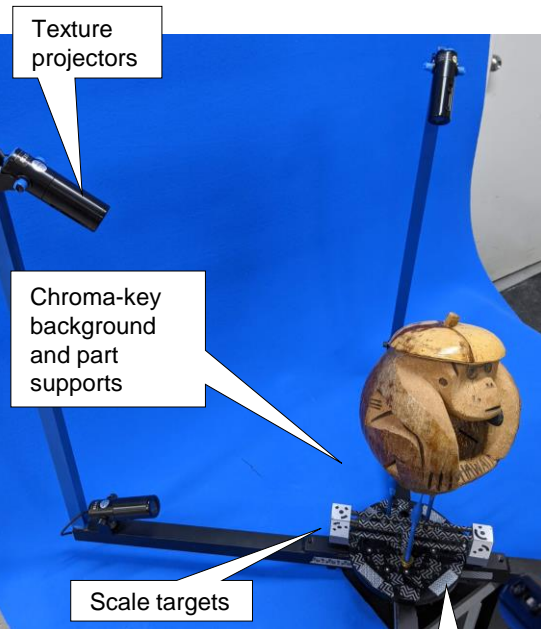
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# PASS: Part Automated Scanning System

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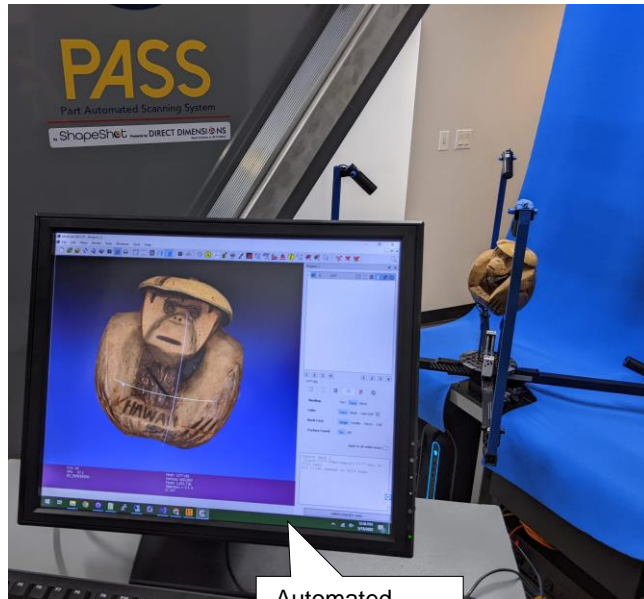


Texture projectors

Chroma-key background and part supports

Scale targets

Turntable



Automated scanning and processing

**Add a new part:**

NSN: 456

Description: bracket

Cage Code:

Project #:

Notes:

Operator:

Background:  Green  Blue

Size:  Large  Small

**Add to Queue**

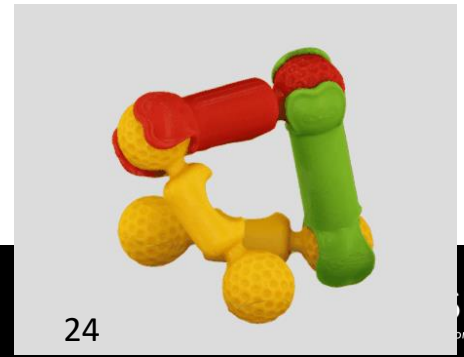
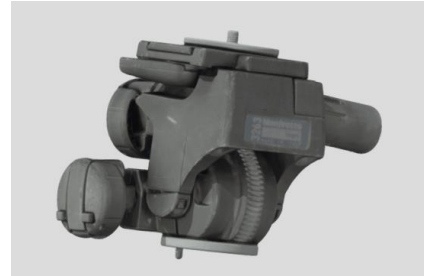
Filter:  **Apply** **Clear**

To Be Scanned	To Be Processed	To Be Reviewed	Accepted	Archive
930	1234_11-4-2021_12:53:41_PM	Widget	1234	
929	333_11-4-2021_9:50:14_AM	pi 55	333	
928	_11-4-2021_9:35:53_AM	focus		

**Scan** **Focus** **Show Info** **Delete**

UI

# PASS Scan Examples

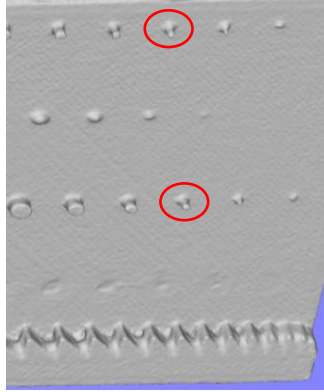


# Resolution

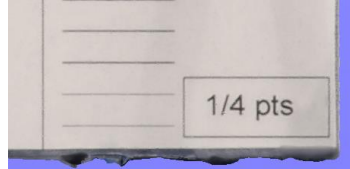
Test artifact:  
3D-printed  
card with  
progressively  
smaller  
features



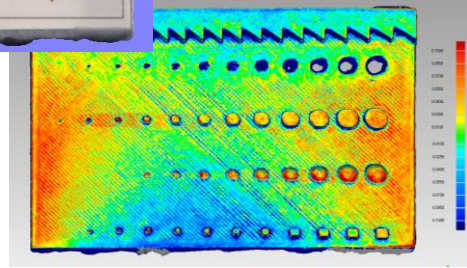
Color texture captures fine details (e.g. print lines) that geometry can't.



1 mm geometric features reproduced.



88 micron lines visible.



Deviation map (photogrammetry vs. structured light), +/- 0.1 mm scale.

Accuracy  
Test  
Artifact:  
4.000000"  
sphere



**W Sphere 1 Properties**

Parameters

Center: -5.0694, -27.8115, 1.0688 m

Direction: 0.0000, 0.0000, 1.0000

Principal: 1.0000, 0.0000, 0.0000

Diameter: 101.5900766 m

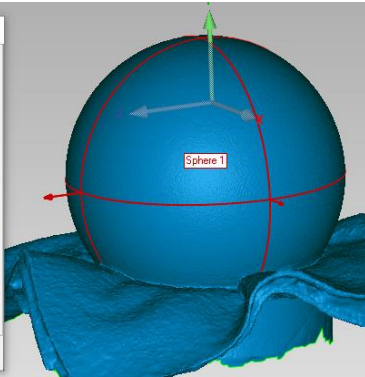
Solidity: Solid

---

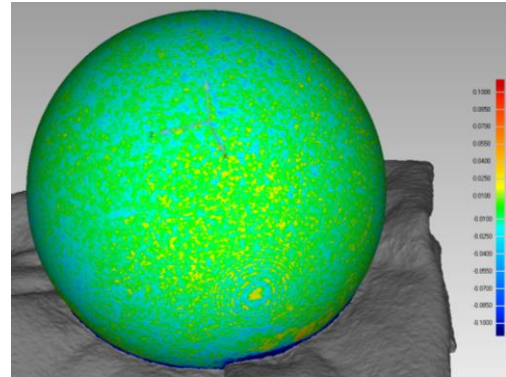
Fitting Statistics

Property	Value
1 Number of Points	293565
2 Maximum Negative	-0.0610 m
3 Maximum Positive	14.2018 m
4 Standard Deviation	0.1404 m
5 Form	14.2628 m

OK

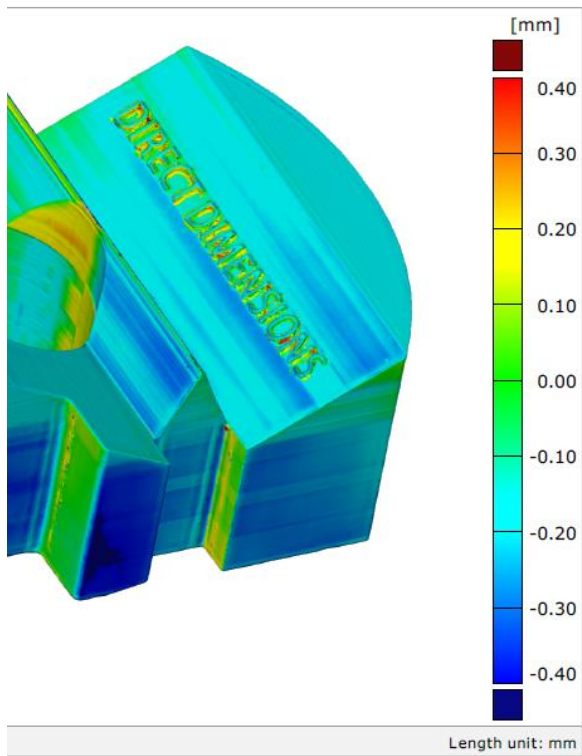


Sphere best-fit to scan geometry matches reality with 10 micron accuracy. Target: +/-19 microns.



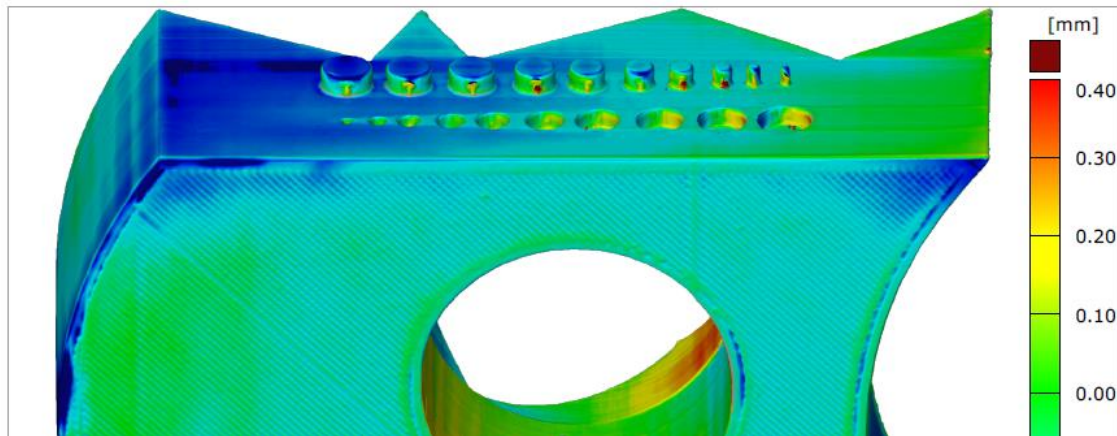
Deviation map shows high-frequency noise with +/- 10 micron amplitude.





## Desired scanning system capabilities for inspecting AM parts:

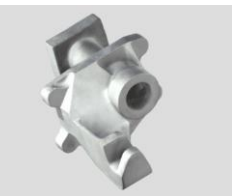
- Detect AM-specific quality issues (e.g. scale errors, non-uniformity of layers, voids, surface flaws indicative of a strength issue).
- Capture the complex geometries typical of an AM part.
- Has >4x better accuracy than the part's required tolerances ( **+/- 19 microns**).
- Supports a workflow where every part is different.
- Workflow can be integrated with part production.
- Automated scanning and report generation.



Add a new part: Filter:

	To Be Scanned	To Be Processed	To Be Reviewed
NIN	456		
Description	bracket	scanId	scanName
Cage Code	930	1234	11-4-2021 12:53:41 PM
Project #	929	333	11-4-2021 9:50:14 AM
Notes	928	11-4-2021 9:35:53 AM	
Operator			
Background	<input checked="" type="radio"/> Green	<input type="radio"/> Blue	
Size	<input checked="" type="radio"/> Large	<input type="radio"/> Small	

Add to Queue



Model Review

Was the model acceptable?

Scheduling software sends scanner a queue of parts to inspect, along with their metadata.

Push-button scanning as parts become available.

Automated scan-to-3D-model processing.

Quality control – check for scan quality.

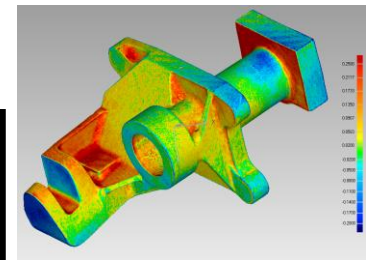
Manual intervention: re-scan.

Automated inspection – compare part to reference model.

Accept or reject part.

Scans and reports stored in database for part traceability.

Manual intervention: re-inspect.



Filter:

scanId	scanName	description	NIN	cageCode	projectNumber	dateReviewed
926	1-11-3-2021_6:01:21_PM	red pt on green filled	1			11/3/2021 6:28:24 PM
925	2-11-3-2021_5:56:05_PM	labeler 2	2			11/3/2021 6:27:50 PM
927	2-11-3-2021_6:02:16_PM	sgillum	2			11/3/2021 6:27:17 PM
924	2-11-3-2021_5:51:46_PM	labeler	2			11/3/2021 6:05:37 PM
919	2-11-3-2021_4:48:54_PM	pyllum	2			11/3/2021 5:33:39 PM
920	2-11-3-2021_4:56:11_PM	date	2			11/3/2021 5:23:09 PM
921	111-11-3-2021_5:00:57_PM	coconut monkey	1111			11/3/2021 5:22:16 PM
918	1-11-3-2021_4:42:18_PM	impellor horiz	1			11/3/2021 4:52:33 PM
917	9-11-3-2021_4:20:21_PM	widgit faby lit	9			11/3/2021 4:40:04 PM
916	5-11-3-2021_11:59:48_AM	widgit3	5			11/3/2021 4:21:44 PM
915	5-11-3-2021_11:36:07_AM	widgit filled not lit	5			11/3/2021 11:51:07 AM
914	8-11-3-2021_10:52:11_AM	widgit2	8			11/3/2021 11:34:38 AM
913	2-11-3-2021_10:46:01_AM	widgit bottoms side lit	2			11/3/2021 11:16:28 AM
912	2-11-2-2021_6:37:45_PM	test widgit some spray	2			11/3/2021 11:56:02 AM
911	1-11-2-2021_6:11:50_PM	test widgit	1			11/2/2021 6:33:16 PM
907	1-11-2-2021_5:11:53_PM	tapemessure	1			11/2/2021 6:17:33 PM
910	2-11-2-2021_6:03:07_PM	casting	2			11/2/2021 6:15:59 PM
908	8-11-2-2021_5:14:56_PM	vert tapemessure large	8			11/2/2021 6:08:11 PM
909	8-11-2-2021_5:17:48_PM	vert tapemessure small	8			11/2/2021 6:05:34 PM
906	9-11-2-2021_4:59:47_PM	casting	9			11/2/2021 5:51:03 PM

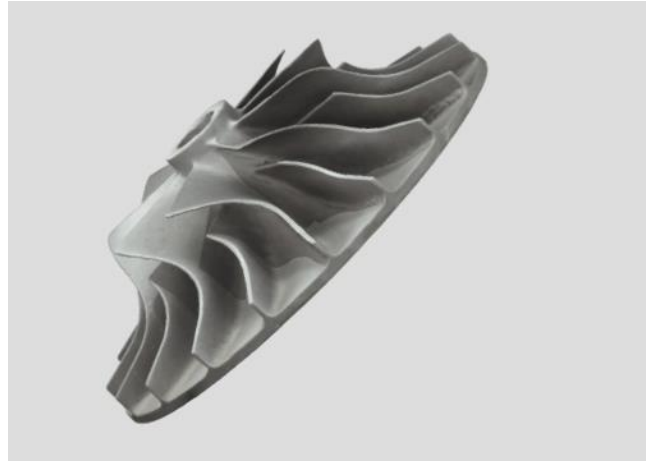
View Model Open Folder Rescan Re-Process Show Info Export Delete Reject



# PASS Automated Inspection



3DF Zephyr



Capturing Reality RealityCapture



Agisoft Metashape



**Photogrammetry Software Options**

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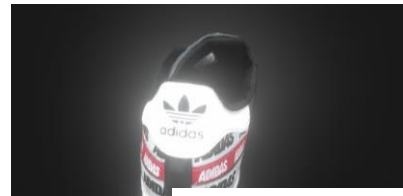
# As cameras, drones, and GPUs become cheap and ubiquitous, so will photogrammetry

## In the news:

- Apple released photogrammetry software
- **EPIC Games** buys **Capturing Reality** (photogrammetry software creators)
- **Capturing Reality** just released phone-based *RealityScan* software

## Trends:

- Combining photogrammetry with other measurement techniques for targetless scale and detail
  - LIDAR
  - Flash-LIDAR (iPhone)
  - Photometry (shape-from-shading) for extreme high-frequency resolution
  - Accuracy will continue to improve



Scan using an iPhone and Polycam software



Credit: RealityScan



Scan using LIDAR and photogrammetry



Bullet casing striations imaged with photometry



# PASS: Future Upgrades

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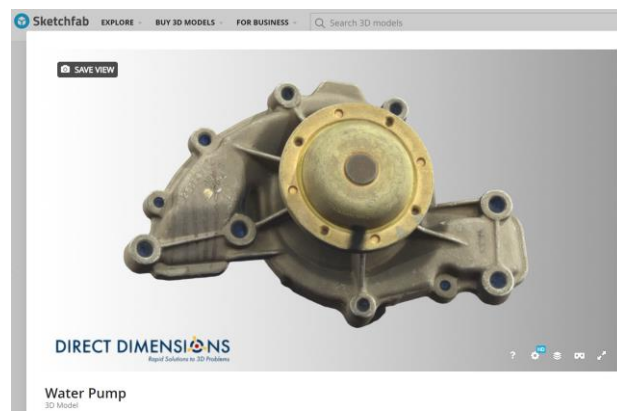
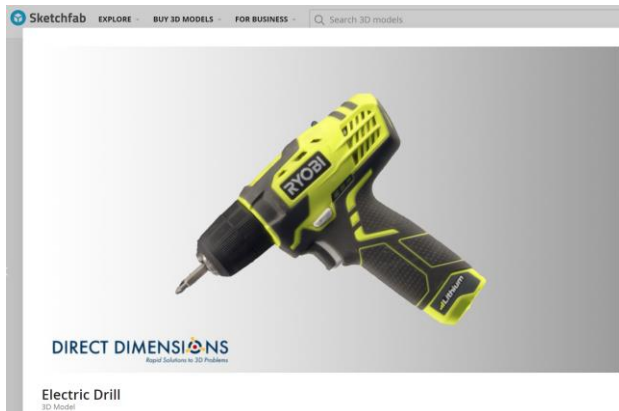
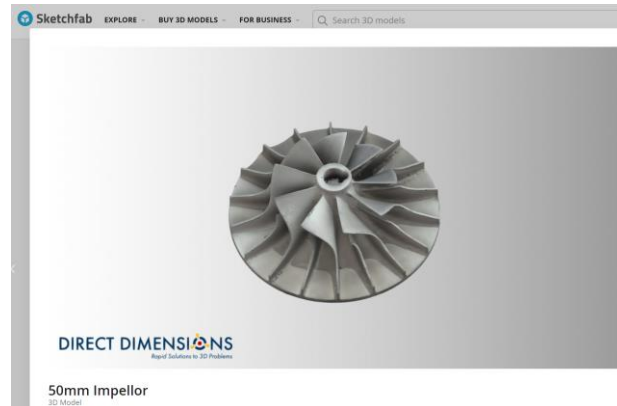
# DIRECT DIMENSIONS

[directdimensions.com](http://directdimensions.com) | [sales@direct.com](mailto:sales@direct.com) | 410-750-0980



**PASS Demonstration Video**

**DIRECT DIMENSIONS**  
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# PASS Example Scans (click thru)

# PASS: Part Automated Scanning System

[Demonstration Video](#)

[Sample Models](#)

[Informational Spec Sheet](#)

[White Paper](#)

DIRECT DIMENSIONS 

[\*\*Links to More Information\*\*](#)

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# Automated 3D Scanning System for Small Part Digital Twins

Photogrammetry **is** a viable option for automated 3D scanning:

Unique abilities:

- Fully automated workflow including scanning, processing, and analysis
- Superior color visualization

Performance benchmarks:

- Accuracy: +/- 10 microns (0.1 camera pixel).
- Geometric resolution: 1 mm (40 camera pixels).
- Visual resolution: 80 microns (3 camera pixels).

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## Summary and Questions?

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