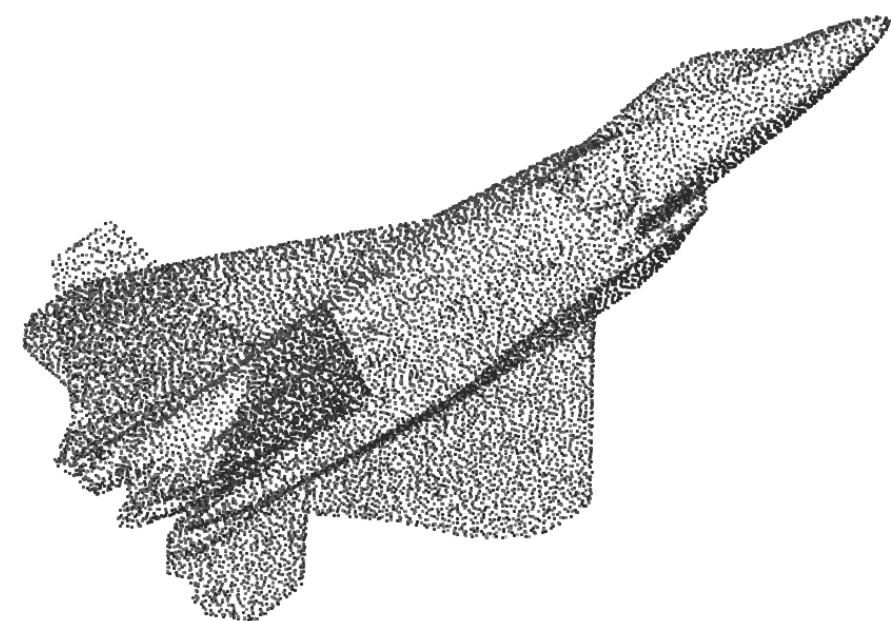


NASA ISIW 2017

High Precision Industrial 3D Metrology Technology for Aerospace Applications

Steve DeRemer

January 31, 2017



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- Self introduction
- 3D Measurement technology
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- ATOS – Inspection – Reverse projection
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- Case study: DSR German Aeronautics and Space Research Center
- Turnkey Non-Contact Measurement and Inspection Integration into Industrial Processes:
TRITOP, ATOS ScanBox
- Gom Inspect

Capture 3D, Inc.

- **North American Partner of GOM GmbH Optical Metrology Solutions (Braunschweig, Germany)**
- Over **10,000** GOM systems installed worldwide
- Capture 3D established in 1997
 - ❖ Costa Mesa, California (Headquarters)
 - ❖ Connecticut
 - ❖ Michigan
 - ❖ North Carolina
 - ❖ Washington
- Dedicated Automation and Support teams in Michigan facility
- Steadily growing and comprised of 60% engineers



Background: Steve DeRemer



Technical Application Specialist

Started with Capture 3D in 2010

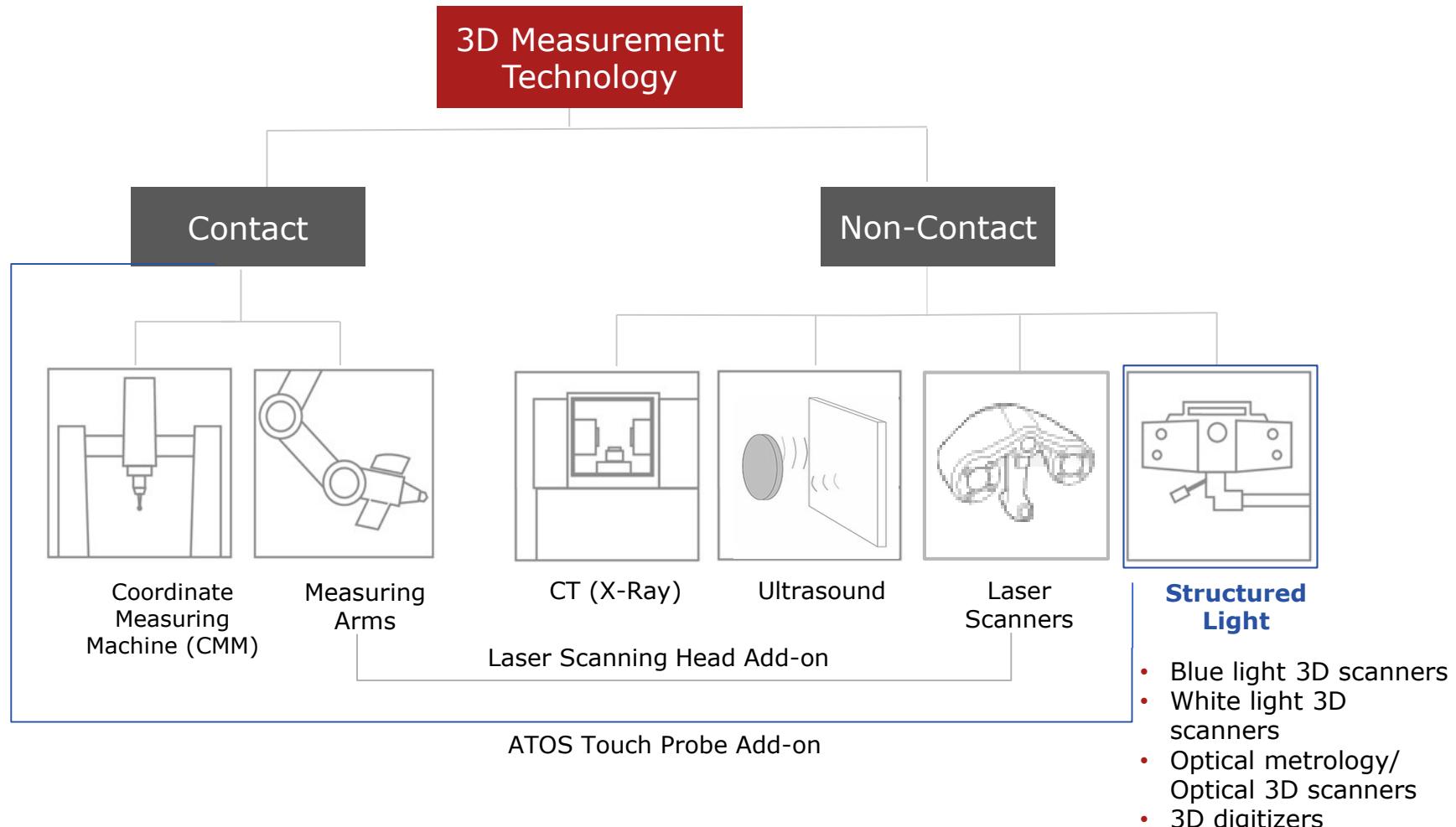
20+ year career in the metrology field utilizing various types of metrology technologies

Tasked with helping companies optimize manufacturing processes with metrology, identify unique applications, and collaborate with companies on process improvement techniques.



MBA - Walsh College of Accountancy and Business
BS Computer Aided Design - Eastern Michigan University

3D Measurement Technology



Tactile vs. Optical Non-Contact Metrology

Tactile methods

- Advantages
 - Established technique
 - Quick, with small number of inspection features
- Disadvantages
 - Slow on free-form surfaces
 - **Long running times, little data**
 - Component holders needed
 - User-dependent alignment
 - Often can't be moved (non-portable)



Optical methods

- Advantages
 - Fast, **full-field** measurement
 - Complete data capture
 - Mobile – moves toward the object
 - Flexible – different object sizes
 - No fixture or stable components needed
 - Variable alignment
- Disadvantage
 - Slow for small number of inspection features

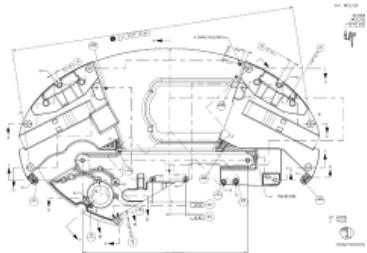


Tactile vs. Optical Non-Contact Metrology

Capture
Customer focused.
Precision driven.

Tactile methods

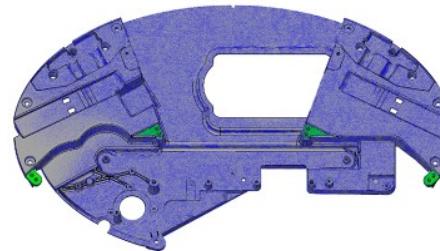
- Measurement of inspection features according to drawing



Prüfergebnisse

Optical methods

- Evaluation of the 3D point cloud



Capture
Customer feedback

Capture 3D

Project: BMW
Date: 07/01/2005
Inspector: Jan Thesing

Alignment: RPS
Part-Nr.: 2034342_M_L_A.CAF
Location: Bremen/Bremerhaven
Company: GOM mbH
Software: Application
ATM: Party-6
Charge-Nr.: 6
Version: 4.0

Result Reports

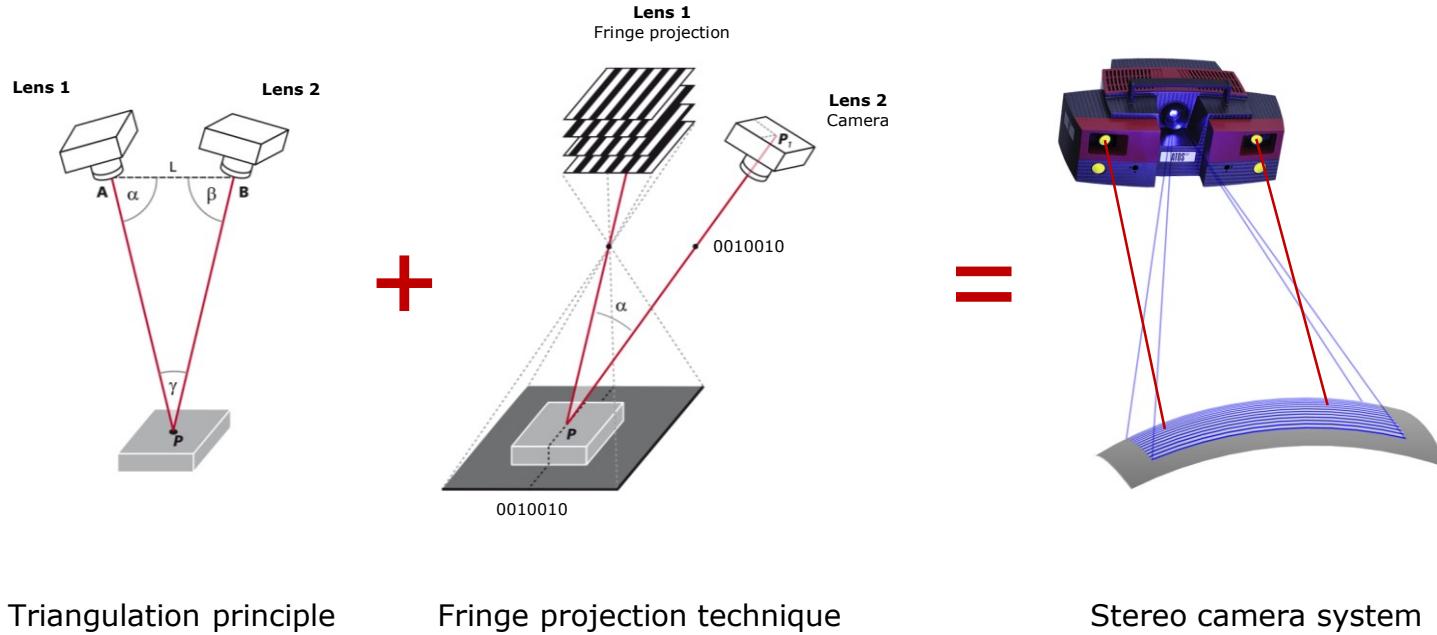
Name	Nominal Coordinate [mm]	Measured Coordinate [mm]	Tol. [-mm]	Tol. + [mm]	Difference [mm]	Tol. Var.
General	Point 10		-0.20	+0.20	0.72	Passed
X	287.00	2356.94	-0.20	+0.20	-0.15	Passed
Y	661.68	661.50	-0.20	+0.20	0.18	Passed
Z	667.96	667.17	-0.20	+0.20	-0.09	Passed
Name	Point 11					
General			-0.20	+0.20	-0.04	Passed

Industrial 3D Coordinate Measurement with ATOS



Stereo camera system

Using the triangulation principle in conjunction with the fringe projection technique, precise 3D coordinates are captured by the stereo camera system.



Triangulation principle

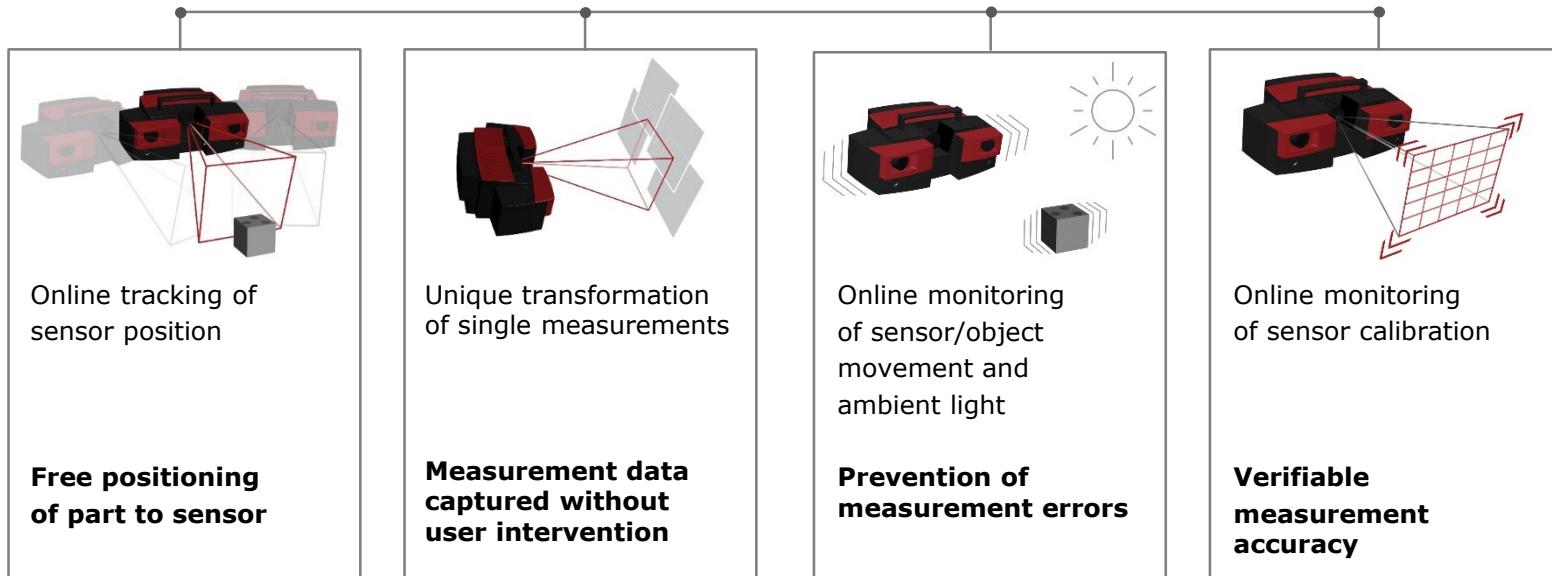
Fringe projection technique

Stereo camera system

Industrial 3D Coordinate Measurement with ATOS



Process reliability in measurement operations

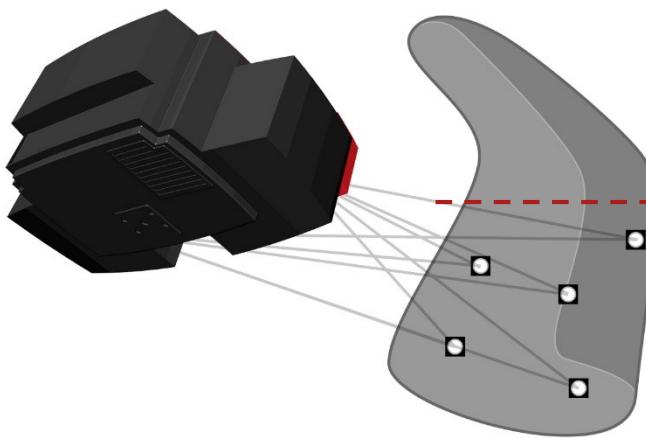


Dynamic referencing results in process reliability during measurement operations
= accuracy

GOM reference point system



Strategies for transformation of single measurements



Measurement without reference points

Measurement with reference points

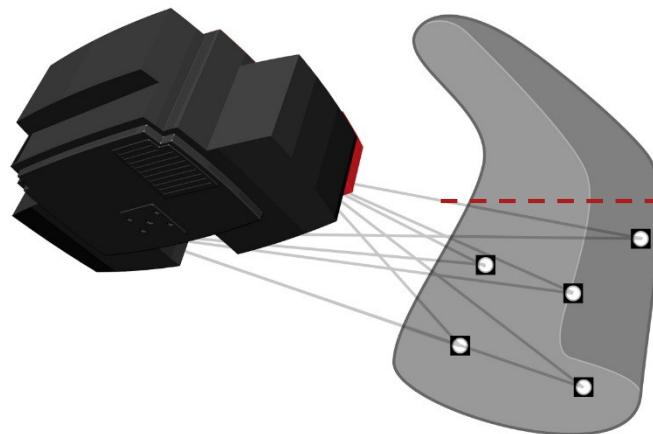
GOM reference point system

Strategies for transformation of single measurements

Both variants can be used in the GOM software

- Only possible with sufficient object geometry

= no process reliability



Measurement without reference points

Measurement with reference points

- Also possible on continuous surfaces

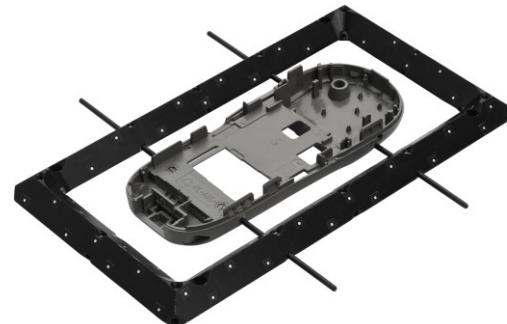
= process-safe measurement strategy

GOM reference frame



Reference frames are designed for collecting reference points easier and faster

- No need to put reference points on parts
- Suitable for small to large parts
- Reduced preparation time
- Quick swapping of parts
- Programmed to acquire reference points only



Innovative Precision Metrology



High Quality Structured Blue Light 3D Scanners

Aerospace certified accuracy

Advanced hardware and high quality optics coupled with intelligent software

Triple Scan Functionality – 3 Sensors in 1 – Reduces # of scans, improved data on shiny surfaces, and better measurement in deep pockets.

Rapid high definition data acquisition

Various configuration possibilities from portable to automated



ATOS Triple Scan



ATOS Capsule



ATOS Compact Scan



ATOS Core
*Available with
Triple Scan
functionality



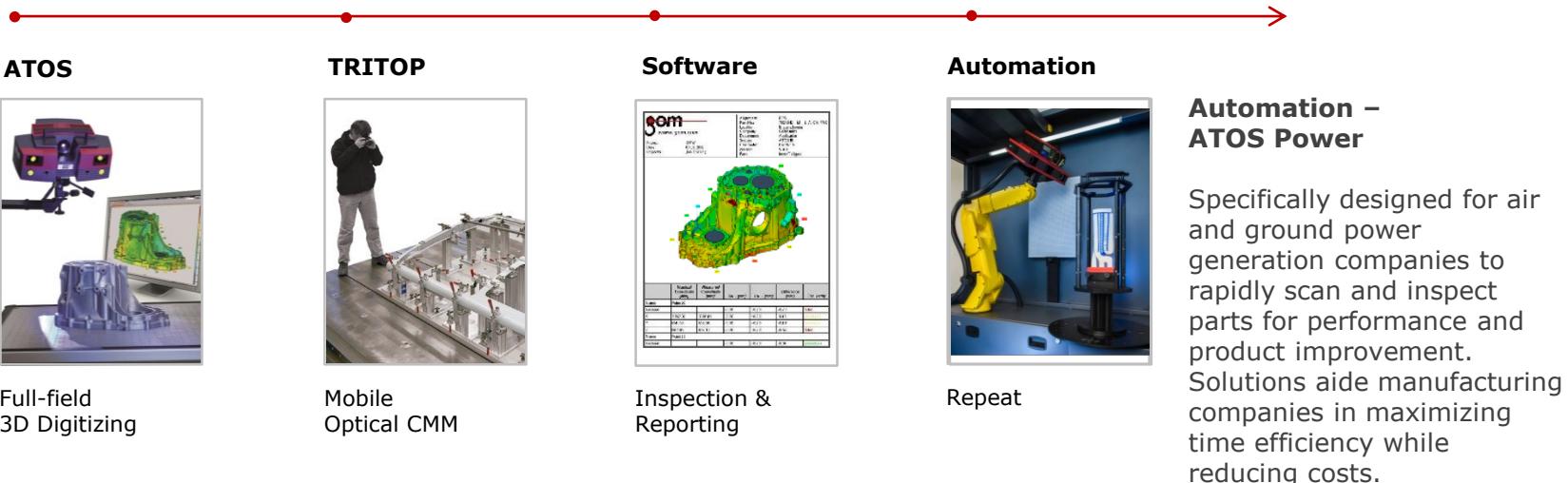
TRITOP

Innovative Precision Metrology



Structured Blue Light 3D Metrology, Inspection, Photogrammetry, and Automation

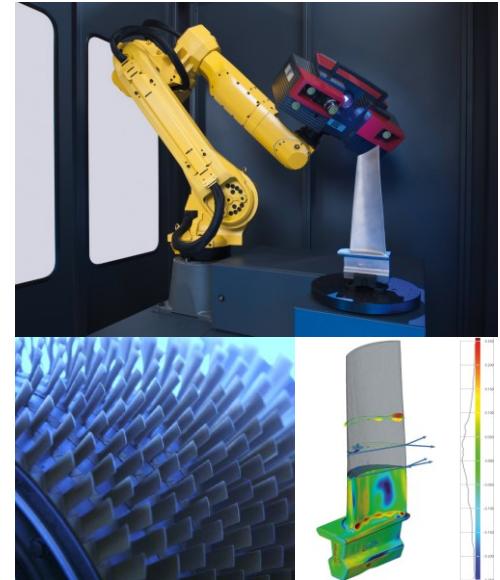
- Shortened measurement setup and data collection time allows companies to focus on true process optimization.
- A high quality color map inspection data on the part, mold, tool, and/or die allows companies to quickly apply the optimal corrective action and accurately predict trends
- Speed up time to market, eliminate iterations and save an enormous amount of costs that were once being spent on rework and waste.



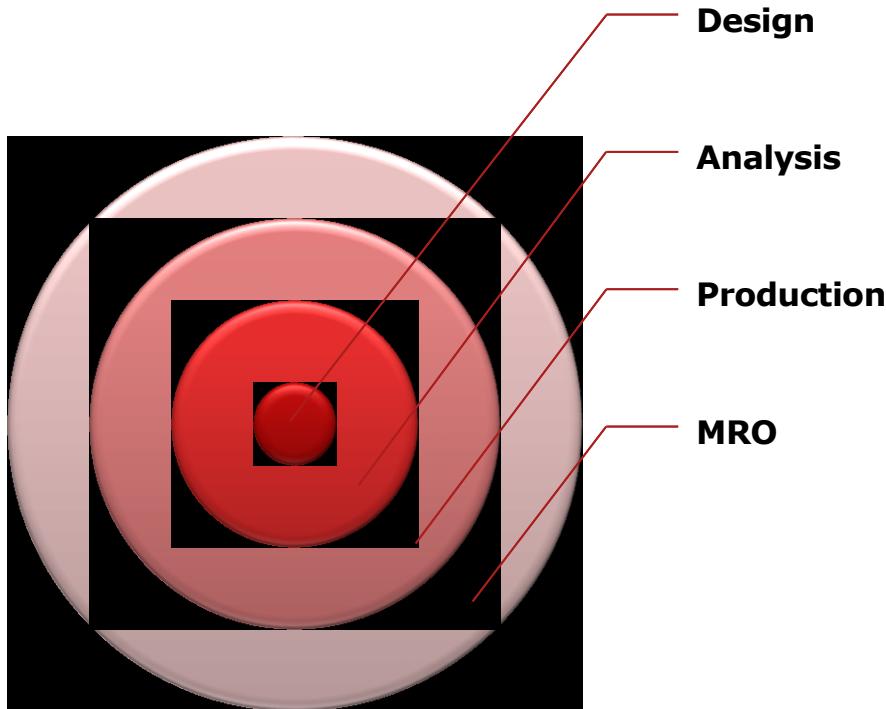
Improving 3D Metrology Applications



- FAI / Quality Control / Root Cause Analysis
- High volume repetitive measurements (trending)
- CFD/FEA /CAE Analysis
- Rapid and Additive Manufacturing
- Adaptive Machining
- Determinant (Digital) Assembly form, fit, and function analysis
- Virtual Assembly Alignment and Predictive / Custom Shimming
- Wing to body / Fuselage mate
- Engine pylon to Wing mate
- Thermal coatings thickness / chemical milling material removal measurements
- Tooling Quantification, Finger Printing and Wear Analysis
- Material characteristic quantification
- e.g. Forming and Stamping – Part Springback
- 1st time digital definition / Reverse Engineering



Improving Engineering Processes



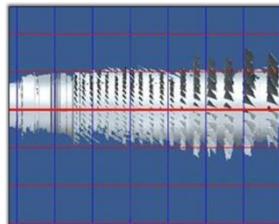
Sharing knowledge throughout the enterprise reducing duplication of effort and improving collaboration between departments and suppliers

Design



Reverse Engineering of Single Components

Rapidly scan components and generate an accurate 3D digital definition to support CAD model creation, capture design iterations, and archive "as manufactured" condition.



Reverse Engineering of Complex Shaped Components

Scan complex shaped components quickly and easily without costly fixturing set-ups. ATOS scanner's high resolution supports the capture of small features such as edges and fillets.



Small Parts Scan

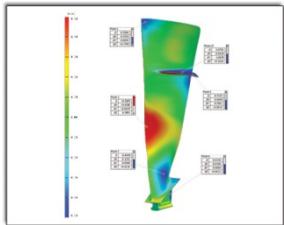
The ATOS 3D scanner's ability to be configured to various size measuring volumes supports the accurate scan capture of very small features such as edges, fillets, and rounds.



Extra Large Parts Scan

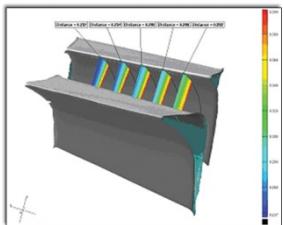
Rapidly measure large turbine buckets to full size aircraft while maintaining a high level of data accuracy. ATOS system flexibility supports extra small to extra large scan projects.

Analysis



3D First Article Inspection

Automatically compare your part's scan data to the CAD model via an easy to interpret visual 3D color inspection map. Instantly see where the problematic areas exist.



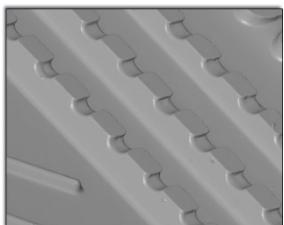
Improve Product Performance

Calculate the nozzle throat total airflow volume by finding the minimum distance between the trailing edge of each vane and the face of the adjacent vane.



Ceramic Cores Analysis

Inspect core dimensions, shrink rates, trip strips, and blisters to tooling to effectively modify molds/tooling for accurate part manufacturing.



Turbulator Measurements

Scan complex and small turbulator features. Measure tight areas between blades.



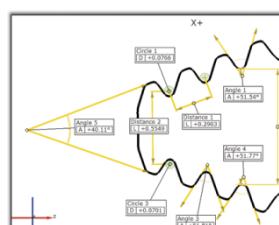
Digital Assembly

Accurately compare scanned components and assemblies vs. CAD. Interrogate mating components to solve assembly, form, fit and finish issues.



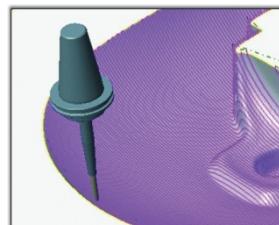
Overall System Performance Improvement

Create an "as manufactured" digital assembly, instead of CAD nominal. This digital definition can be utilized for overall system performance comparison, analysis and optimizations.



Dimensional Analysis (2D)

Compare "as manufactured" part scan data to 2D drawings for inspection analysis.



Tool Path Optimization

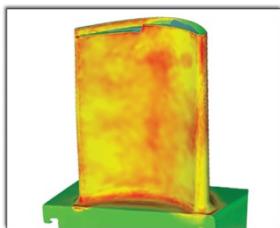
Directly mill from ATOS point cloud data to accurately create tool cutter paths. Broken dies can be duplicated quickly without having any surface reconstruction.

Production



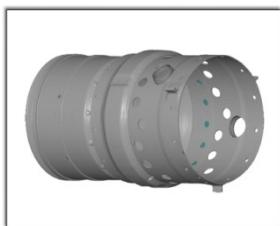
Part Verification

Fast measurement of complex parts delivers accurate and robust dimensional inspection reports including complex features, surfaces, holes, and edges.



Coating Thickness Measurements

Quickly measure before and after coating processes to determine coating thickness without sacrificing parts.



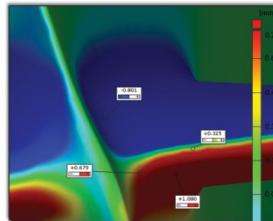
Combustor Measurements

Rapidly measure entire component and extract feature information such as hole diameters, vectors, and locations automatically.



Impeller Wheel Balancing

Scan and calculate center of gravity on castings to position part optimally for "best balanced" machining. Minimize the machining away of material which can be used for future refurbishing.



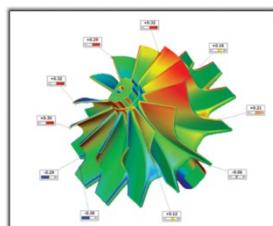
Part and Tool Wear Trends

Identify and document part and tool wear trends. Robust color map deliverable highlights potential problematic areas (part shrinkage, airfoil twist, and tool/mold wear).



Simplified Fixturing

Save time and money by eliminating high precision expensive fixturing. Part position in fixture is not critical providing a simple set-up. Shape and position of part are automatically transformed into a pre-defined coordinate position.



Repeatable Inspections

Measure quantities of parts fast and accurately without operator variability.



Aerospace Certified

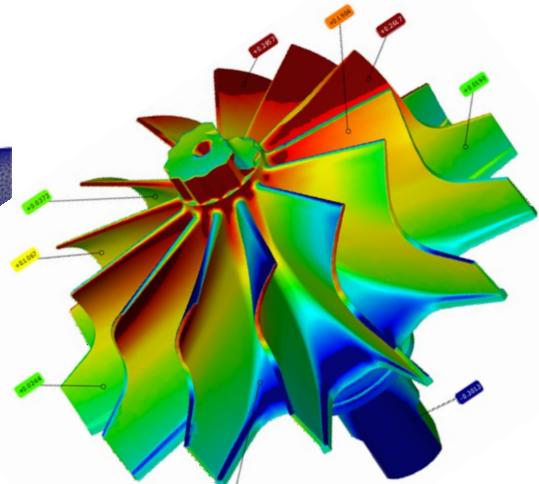
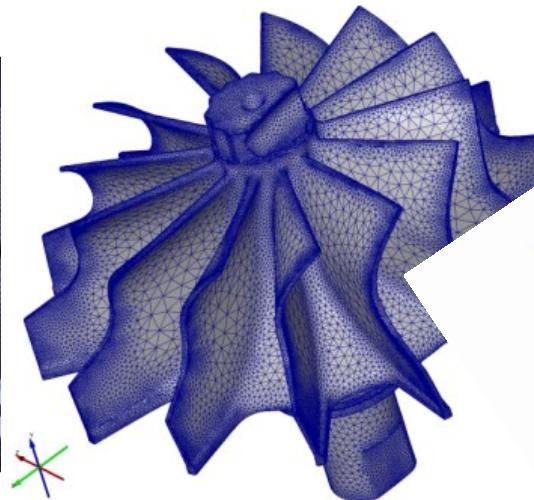
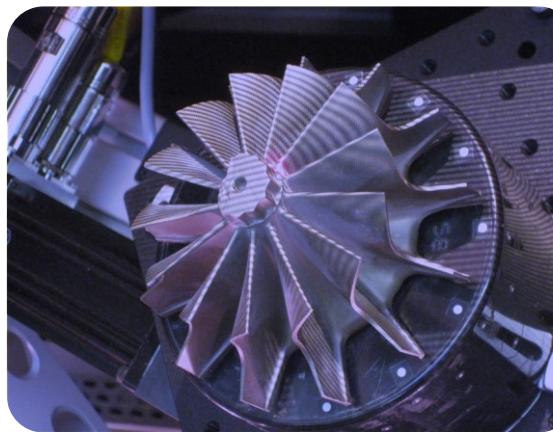
Solutions certified within propulsion/aerospace companies per VDI standards.

MRO



Measure and Inspect Airfoil Blades and Vanes for Repair

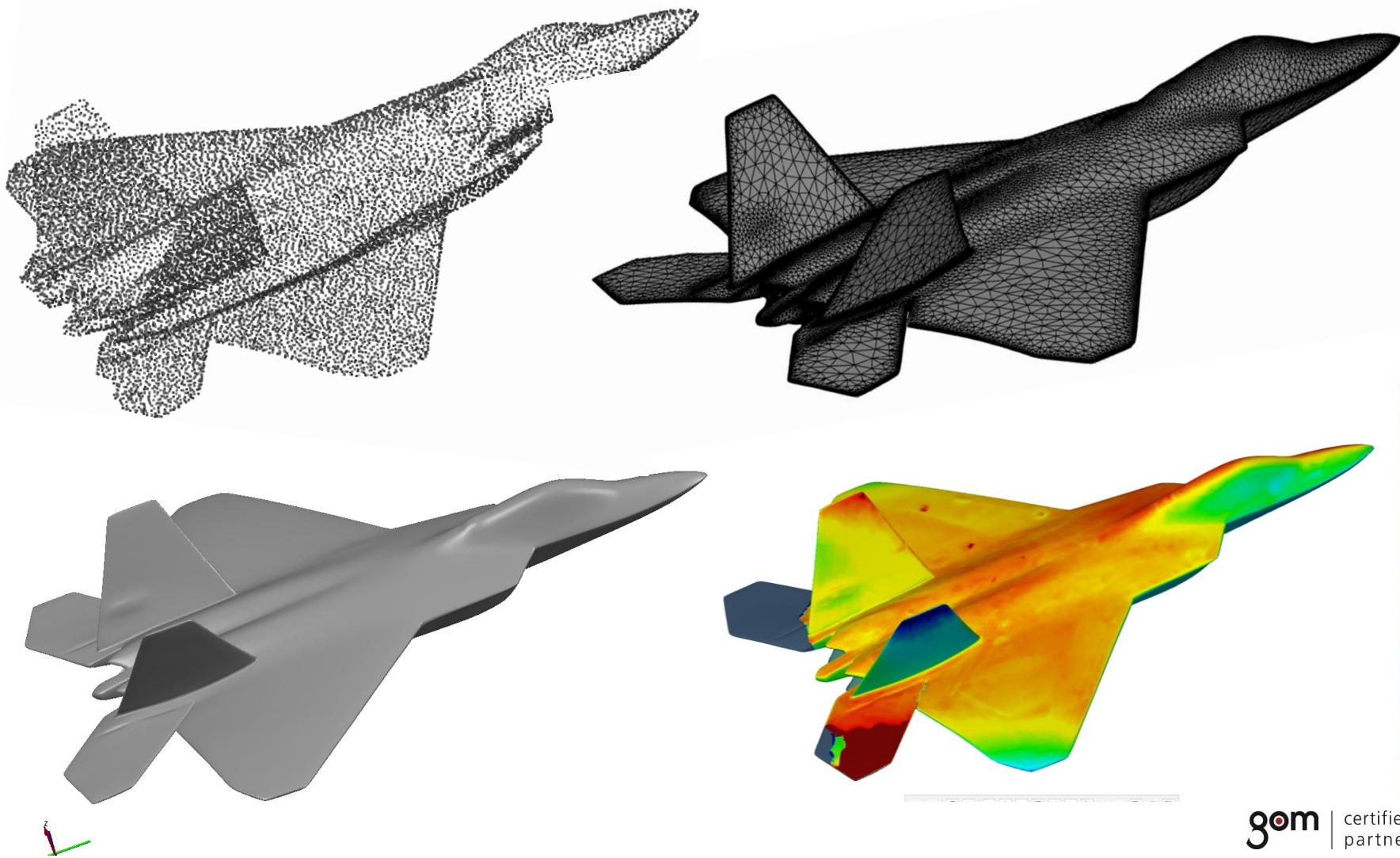
Measure damaged blades to determine extent of damage and optimize repair process. Inspect repaired blade to verify part conformance.



gom | certified
partner

ATOS - 3D Digitizing – High Quality Mesh processing

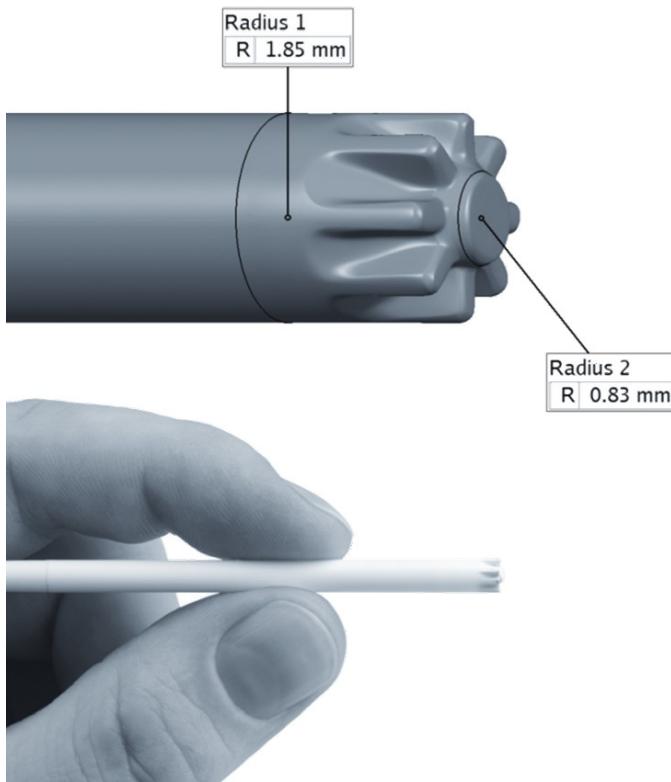
Capture
Customer focused.
Precision driven.
3D



gom | certified
partner

ATOS - 3D Digitizing – Small **As Manufactured** Digital Definition

Capture
Customer focused.
Precision driven.
3D



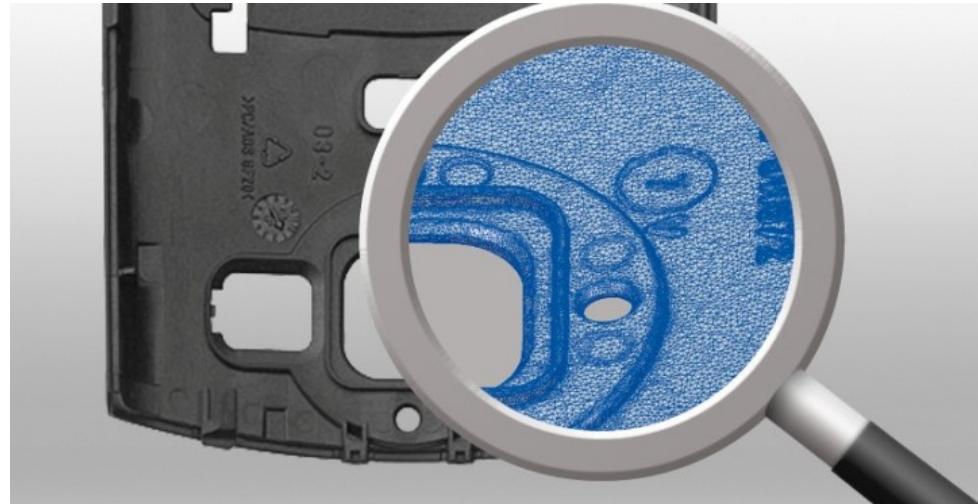
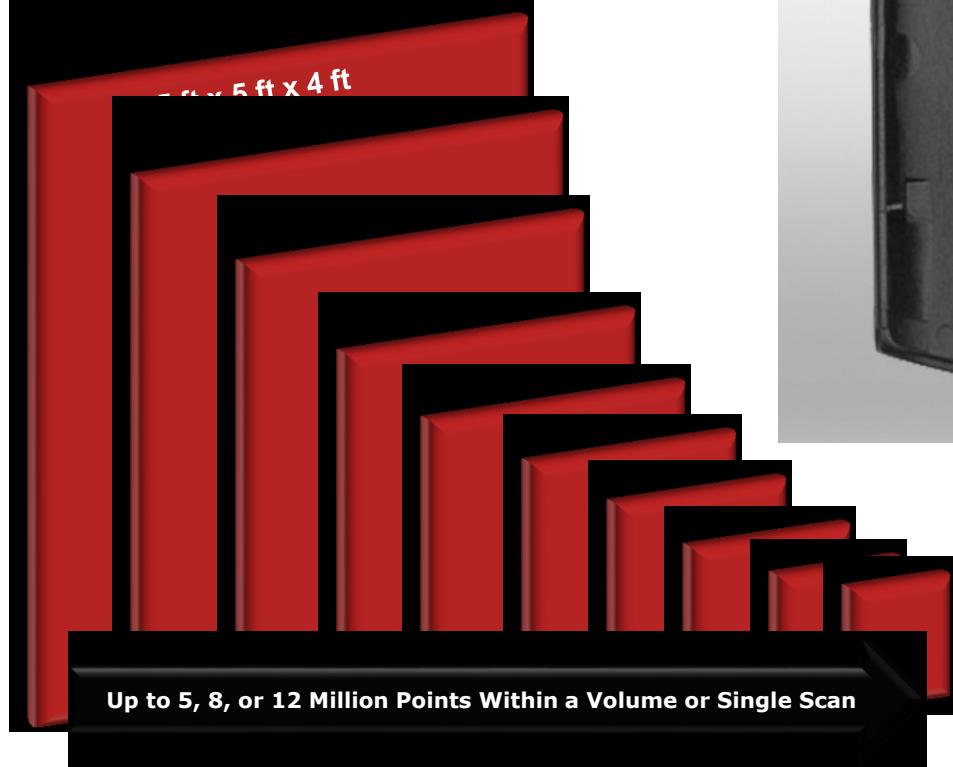
gom | certified
partner

ATOS

Advanced Technology with High Resolution



Each ATOS system has a various range of volumes which can be interchanged to capture a part's finest details.



Flexible fields of view

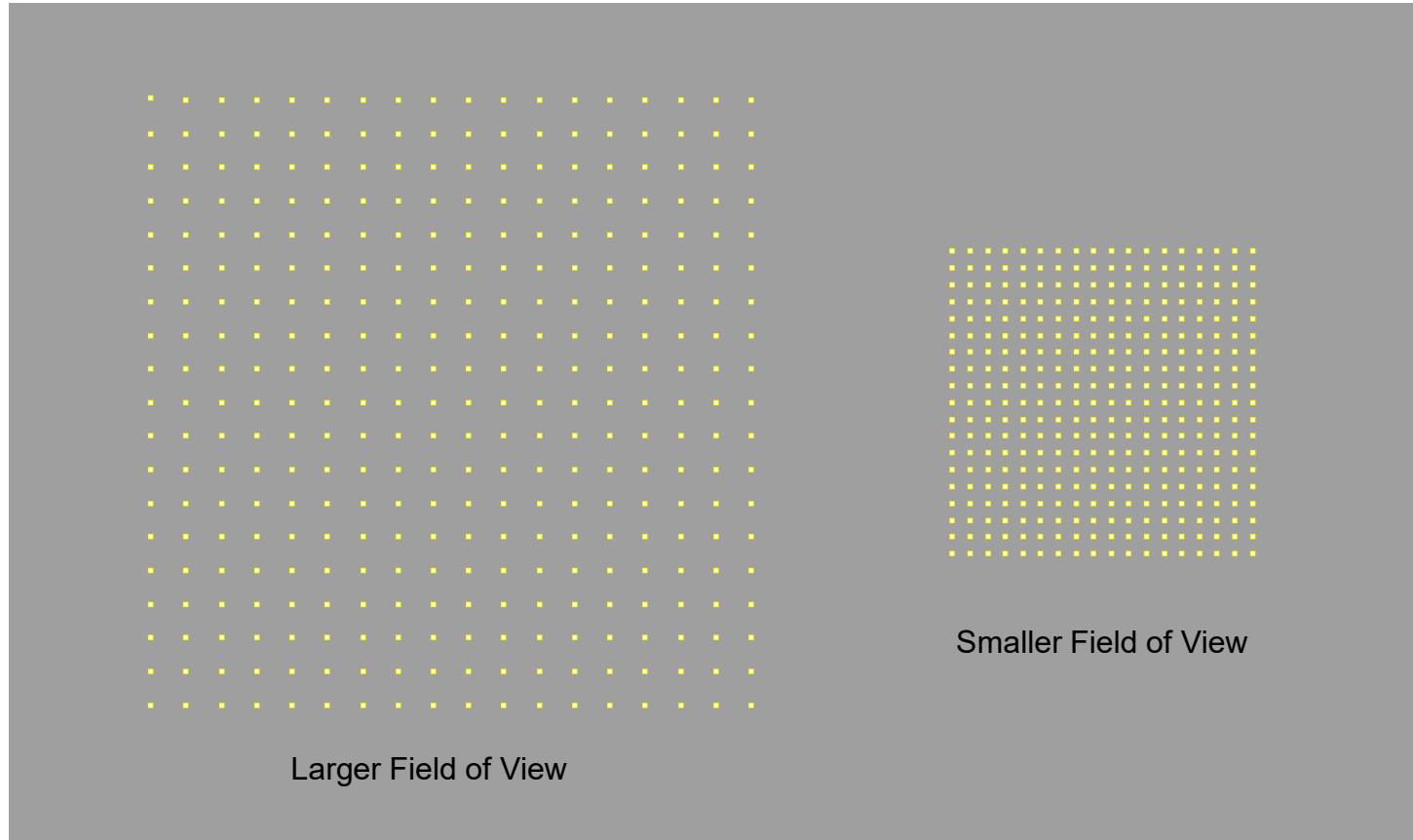
Capture
Customer focused.
Precision driven.
3D



Swapping out lenses

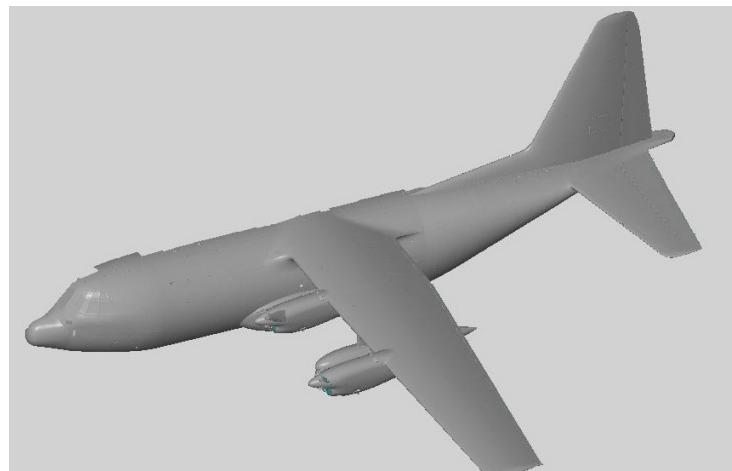
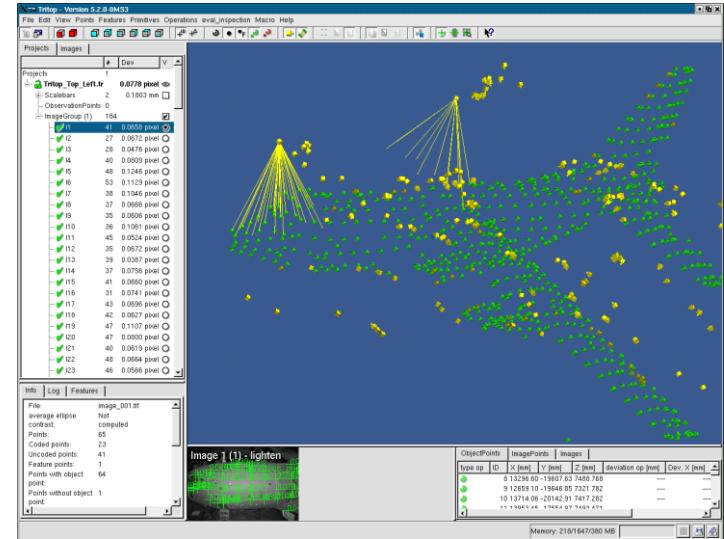
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partner

Measurement Area Size and Resulting Scan Data Density



ATOS - 3D Digitizing – Full size and scale models

Capture
Customer focused.
Precision driven.
3D



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TRITOP Digital Photogrammetry

Capture
Customer focused.
Precision driven.
3D

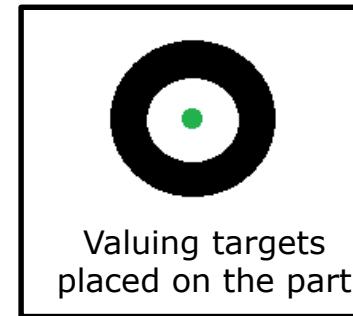
- Non-contact wireless digital photogrammetry system
- Can be used in conjunction with ATOS, or as a stand-alone coordinate measuring system
- High accuracy especially for larger objects
- Independent of environment conditions



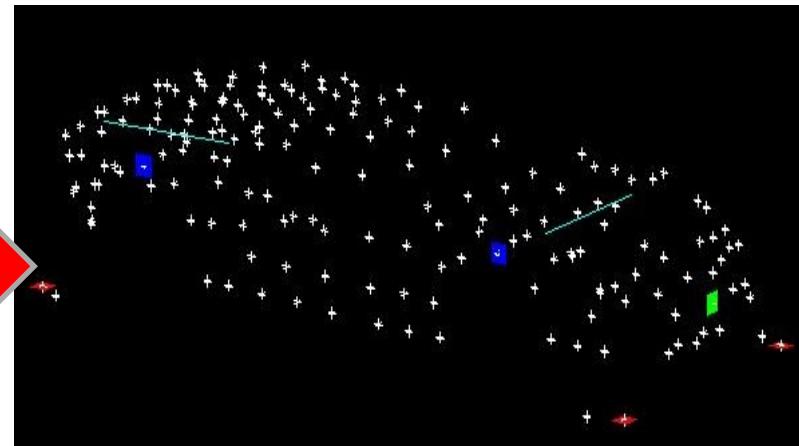
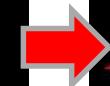
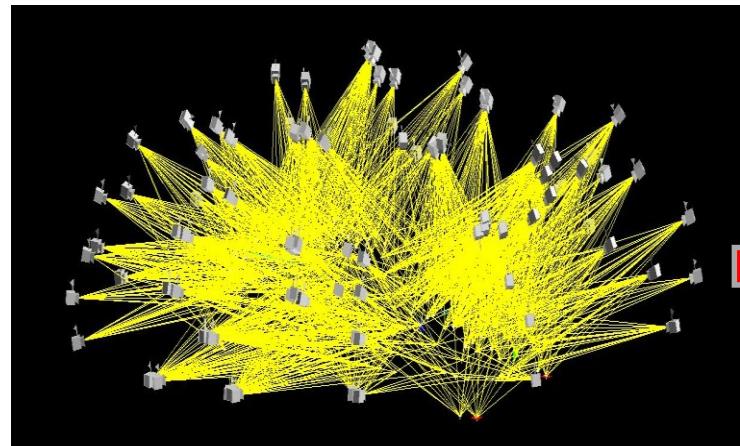
TRITOP – Photo Collection

Images are then 'bundled' into a triangulated 3D constellation

Capture
Customer focused.
Precision driven.

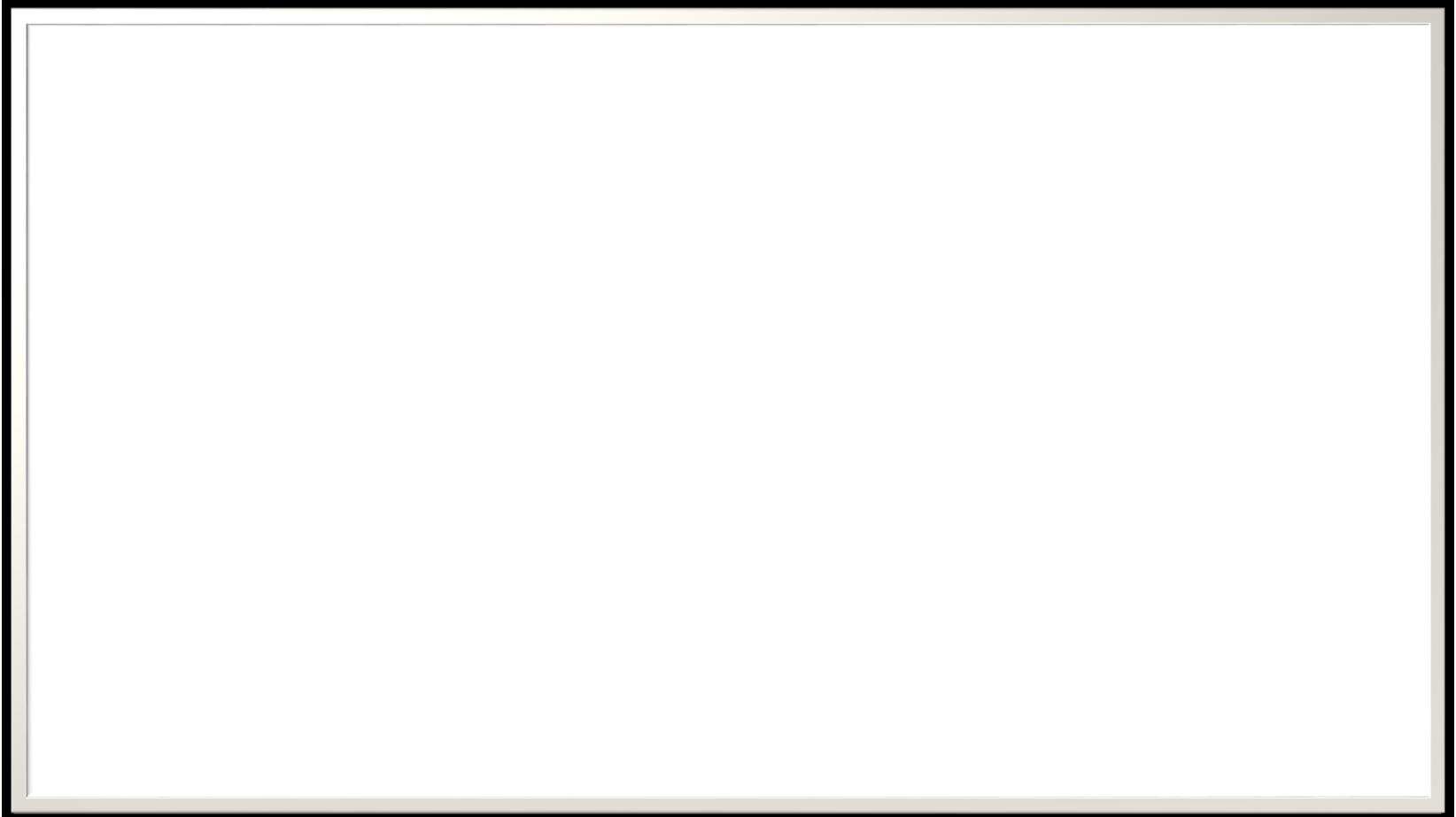


Valuing targets
placed on the part



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TRITOP (Photogrammetry) Output



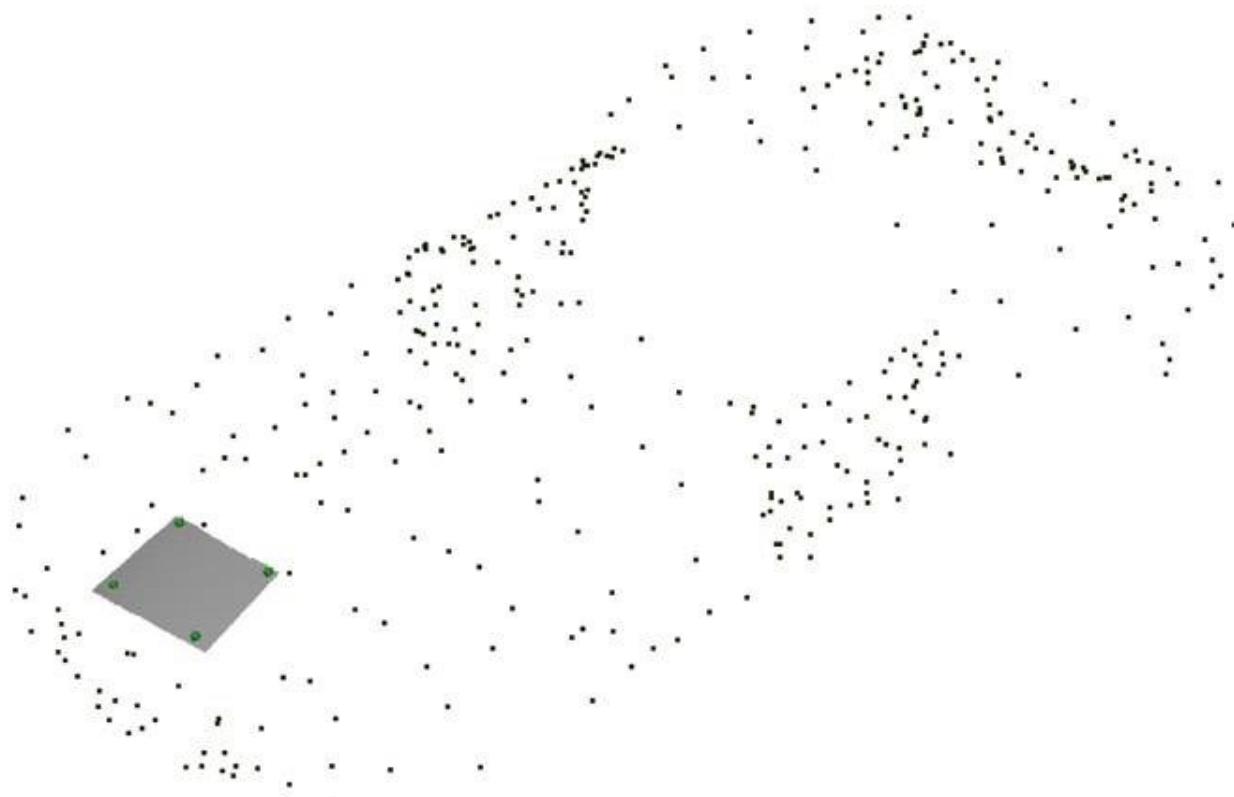
ATOS XL (ATOS + TRITOP) Scanning with fringe projection

Capture
Customer focused.
Precision driven.
3D



ATOS

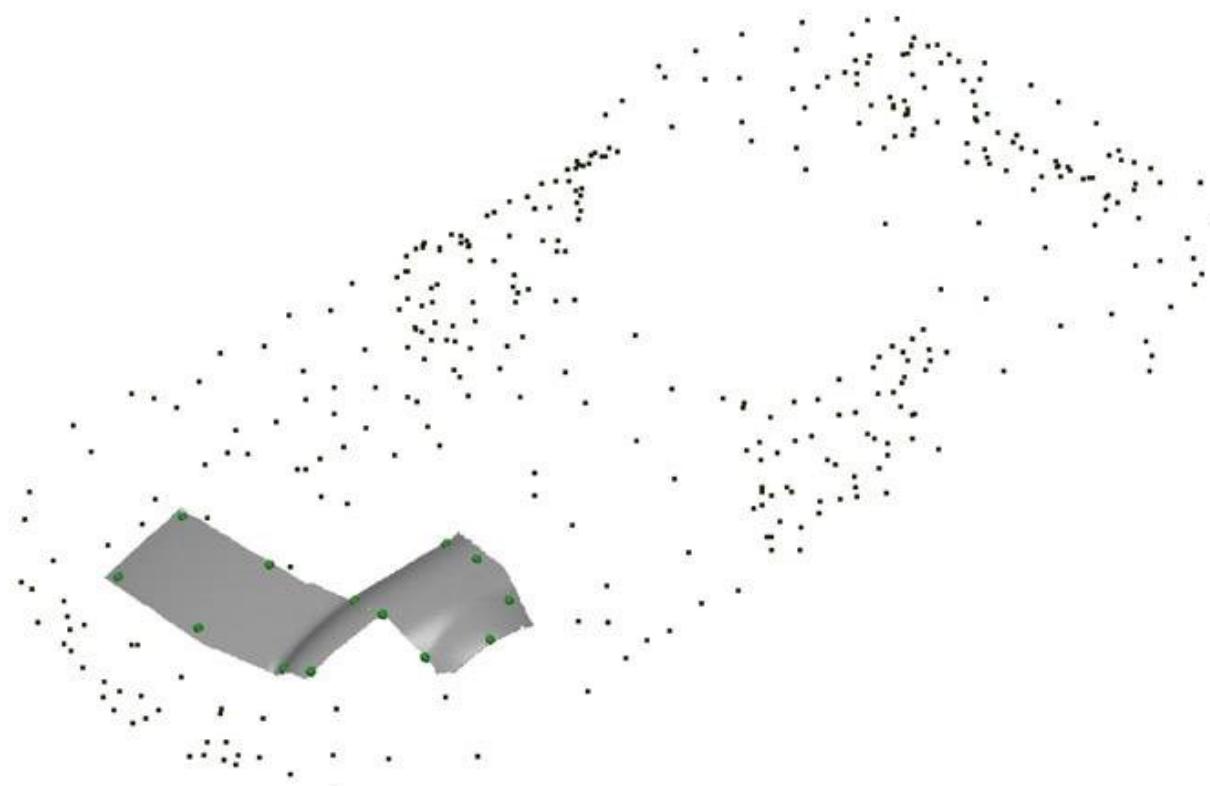
Automatic referencing of individual scans



ATOS + TRITOP

Automatic referencing of individual scans

Capture
3D
Customer focused.
Precision driven.



ATOS + TRITOP

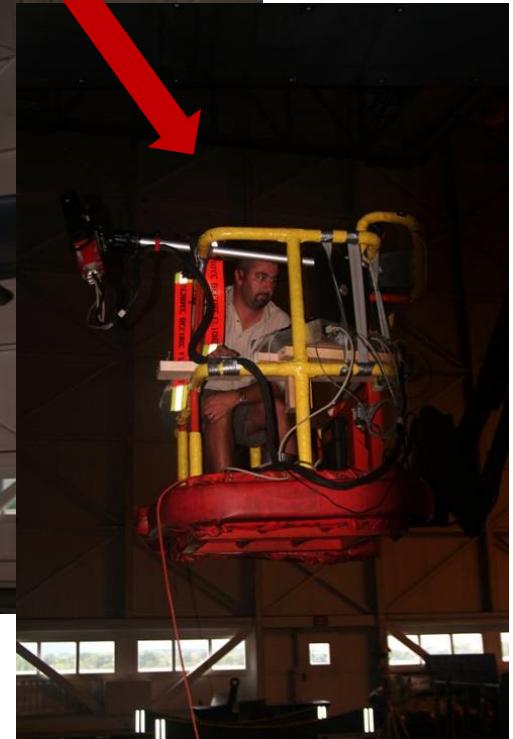
Automatic referencing of individual scans

Capture
3D
Customer focused.
Precision driven.



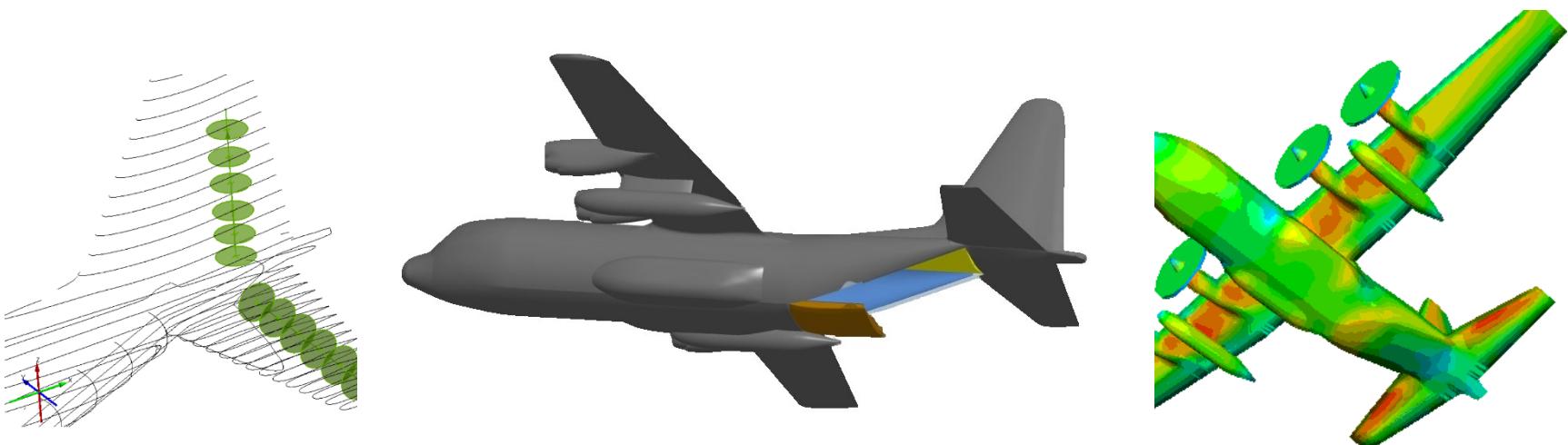
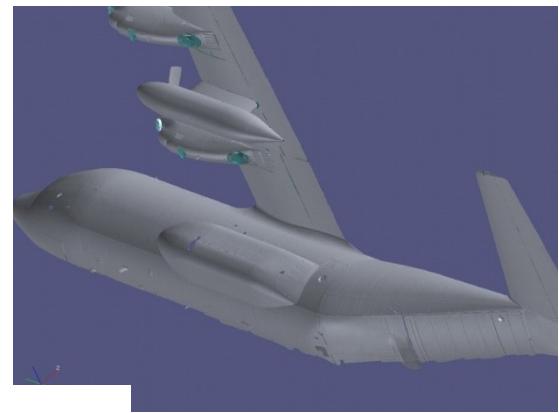
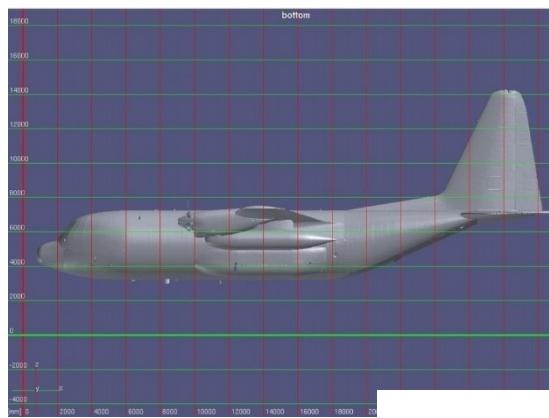
ATOS – NRC C130 RE Analysis

Capture
Customer focused.
Precision driven.
3D



ATOS – NRC C130 RE Analysis

Capture
Customer focused.
Precision driven.
3D



New software functionalities:

- Surface Defect Map
- Reverse Projection

Detection of surface defects based on meshes

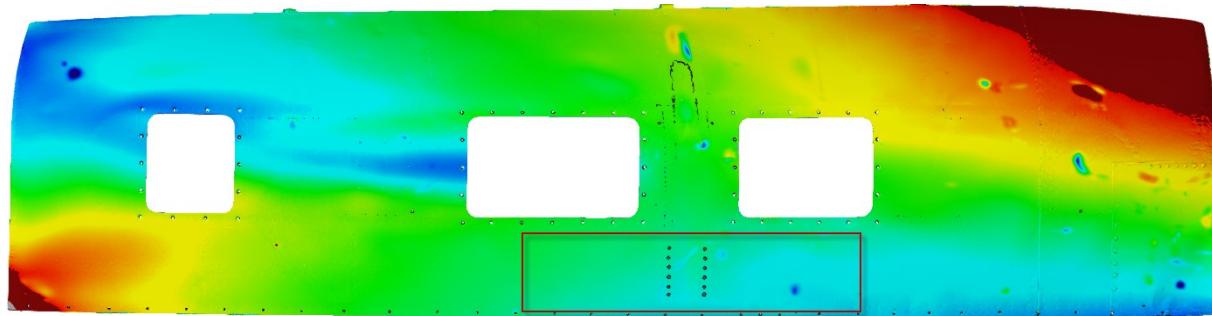
Capture
Customer focused.
Precision driven.
3D



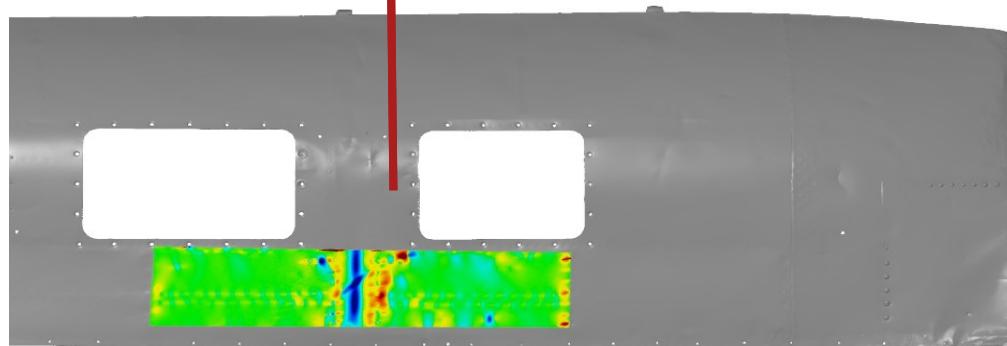
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partner

ATOS – Inspection - Surface defect map

Capture
Customer focused.
Precision driven.
3D



Aircraft panel -
Surface comparison with
0.4 mm tolerance

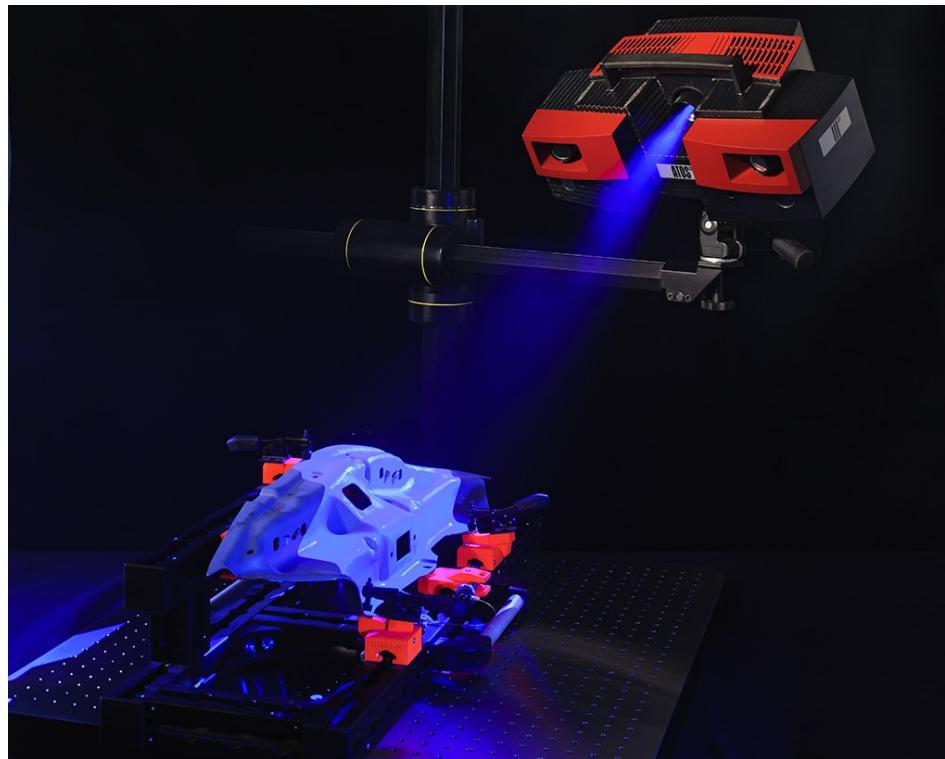


Aircraft panel -
Surface defect map
with 0.4 mm tolerance

“Reverse Projection”



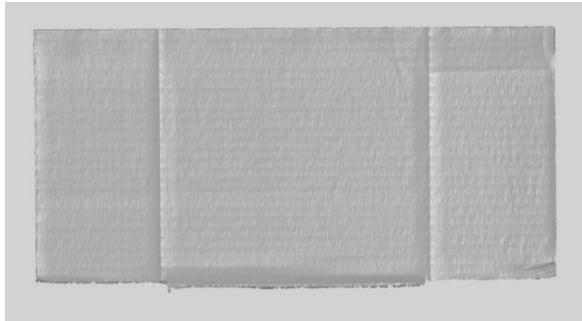
Using the ATOS sensor as both a data collection tool as well as a method to convey the results of analysis



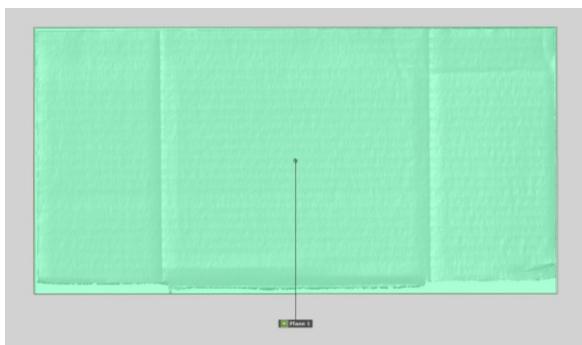
ATOS Triple Scan with Blue Light LED Technology
Capture 3D
www.capture3d.com



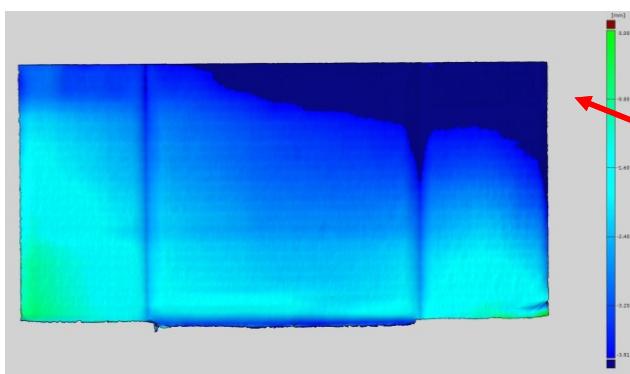
ATOS – Inspection – Reverse projection



ATOS Triple Scan sensor is used to collect the **3D scan data** describing the part geometry



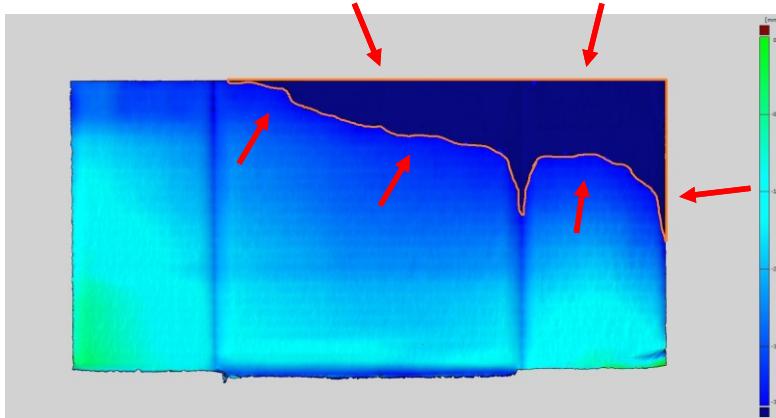
The collected scan data is then **overlaid with a nominal CAD file** (in this case, a best-fit plane)



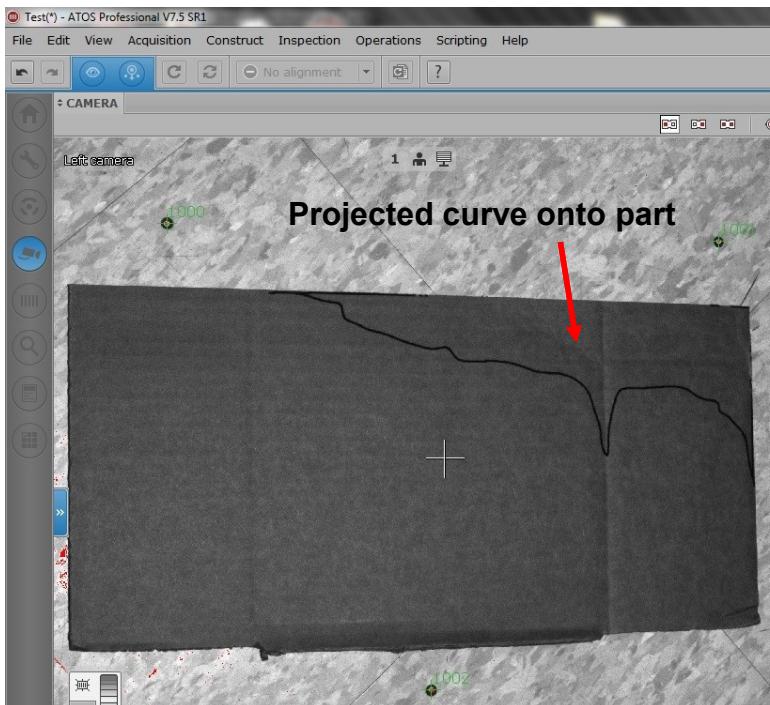
A **comparison** is performed between the nominal geometry and the 3D scan data, identifying an area which is outside the designated tolerance value (dark blue)

ATOS – Inspection – Reverse projection

Capture
Customer focused.
Precision driven.
3D



A **curve** is created by picking points along the boundary of the area that is shown to be out of speculation



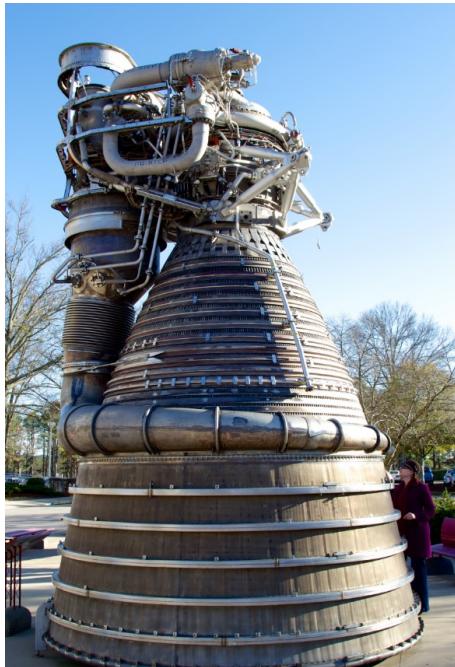
The created curve is then '**reverse projected**' back onto the physical part using the DLP Projection within the ATOS sensor

NASA brought the F1 “moon rocket” engine back to life

NASA and Shape Fidelity worked together to construct a complete and accurate digital assembly of the legendary engine from the Saturn V.

A high-resolution **ATOS 3D scanning with TRITOP photogrammetry** was used to,

- Create a **digital assembly** of the entire engine
- **Scan** and model all of the parts



F1 engine



Detail on an F1
engine injector plate

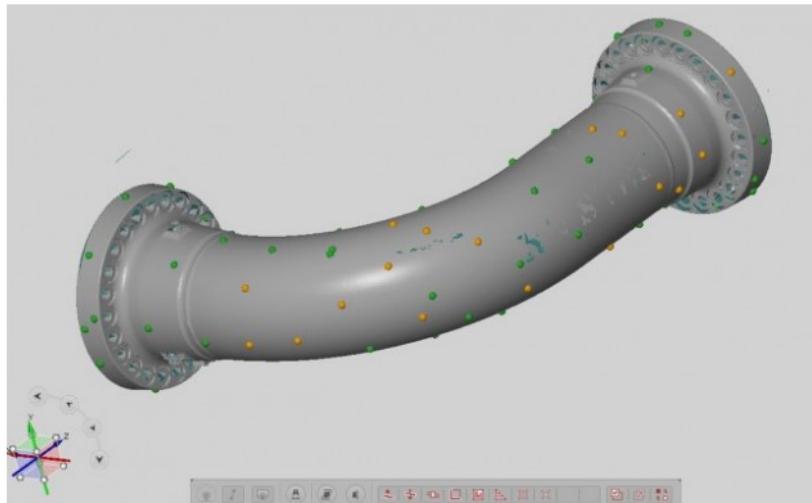
Resurrecting the F1 - Photogrammetry

Capture
Customer focused.
Precision driven.
3D



Resurrecting the F1 - Scanning

Capture
Customer focused.
Precision driven.
3D



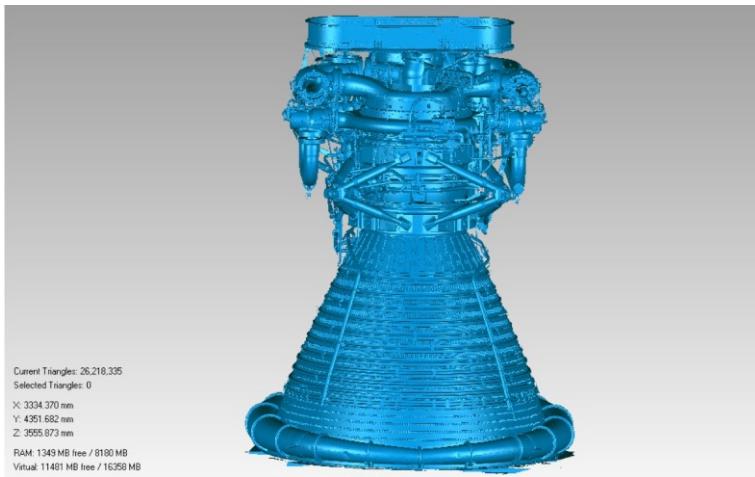
- The same photogrammetry targets were integrated with each scan.



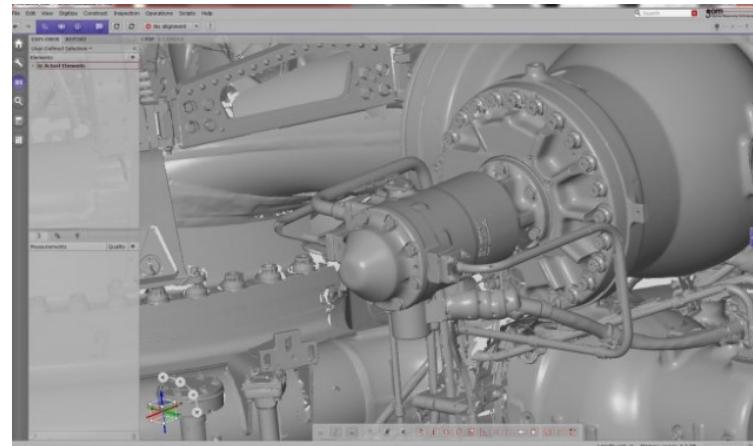
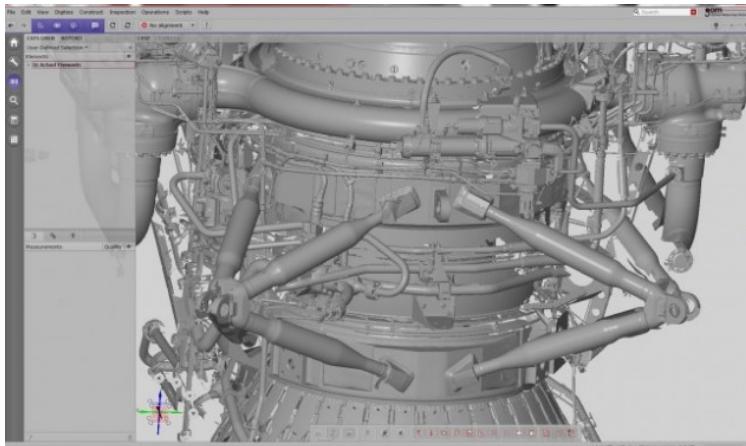
- These targets enabled each individual part to then be re-assembled to its proper position in the digital assembly.

Resurrecting the F1 - Results

Capture
Customer focused.
Precision driven.
3D



- The final composite model, accurate inside and out, made up of all the rocket's thousands of pieces carefully fitted together.



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DLR study – Laminar Flow Structure Feasibility

- DLR (German: Deutsches Zentrum für Luft- und Raumfahrt e.V.,) is the national aeronautics and space research center of the Federal Republic of Germany.
- R&D in aeronautics, space, energy, transport and security for national and international cooperative ventures
- Studied the effects of surface geometry on flow resistance
 - Using Advanced Technology Research Aircraft (ATRA)'s Airbus A320 tailplane
 - Improving **laminar vs turbulent airflow**
 - To improve fuel efficiency
 - To find eco-friendly production method



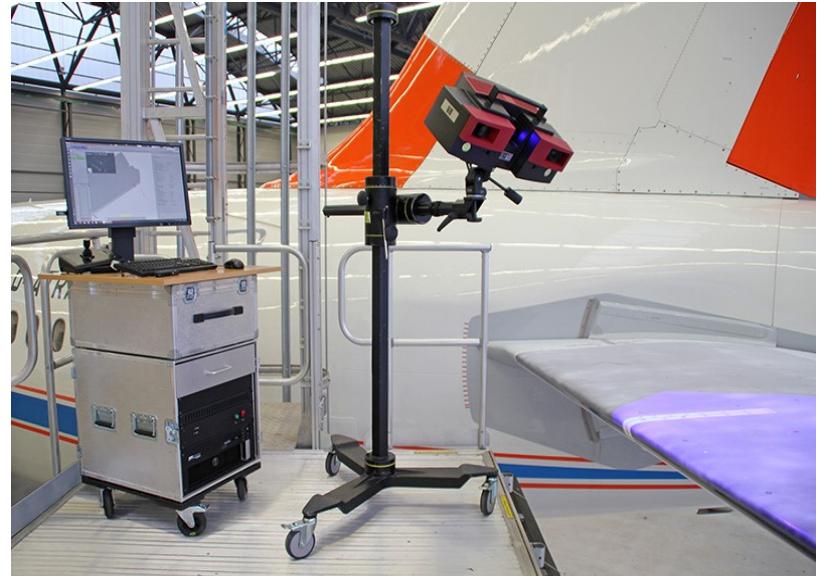
DLR study – Measuring and Testing



Used GOM's optical 3D measuring systems, **ATOS** and **TRITOP**, for measurement and testing.

Goal was to improve the aerodynamics of the aircrafts and optimize the geometry by producing as little flow resistance as possible.

- The first measurement data provided a precise representation of the wing geometry
- The wing was further adjusted in an iterative process in order to represent the displacement of the transition point.
- During the actual flight testing, thermographic measurements were carried out. Five flight tests have shown a positive effect on the geometry change
- As turbulent areas cool down faster, significant thermal differences become visible on the infrared image and were visualized with 3D scanner
- 1.5m x 3m area was scanned in under 15 minutes
- The measurement data was then compared to the component's initial state and perform a full inspection of it with the ATOS inspection software.



DLR study – Findings

Findings suggest that it is possible to,

- ✓ Improve the **performance** of aircraft
- ✓ Allow for more **energy-efficient** production
- ✓ **Reduce** environmentally harmful **carbon dioxide emissions**



This qualitative knowledge will be applied to the wing and fuselage production in the future.

ATOS ScanBox Automation



ATOS automation systems offer:

- ✓ High measuring speed and throughput
- ✓ Repeatability
- ✓ Suitable for any production environment



ScanPort



ScanBox 4105



ScanBox 5108



ScanBox 5130



ScanBox 6130



ScanBox Series 7 & 8

ATOS ScanBox Automation



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Automated Measurement Solution: Double robot cell

Capture
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3D



Automated Measurement Solution: Double robot cell

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Free GOM Inspection Software



Free inspection software allows you to:

- ✓ Perform versatile inspection analyses
- ✓ Process mesh from scan data
- ✓ Create and export reports
- ✓ Improve communication between those who measure, inspect, draw and produce
- ✓ Not only analyze the ATOS data, but also 3D point clouds of whitelight, laser and CT scanners
- ✓ Import, process and analyze everything in one, free software package



Visit www.capture3d.com for download and more information



Capture 3D – Customer focused. Precision driven.

Thank you for your attention.

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