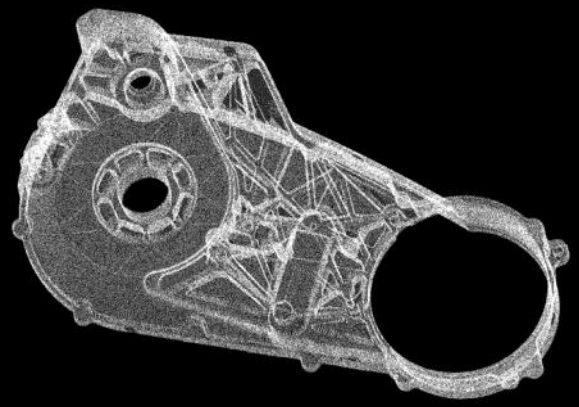
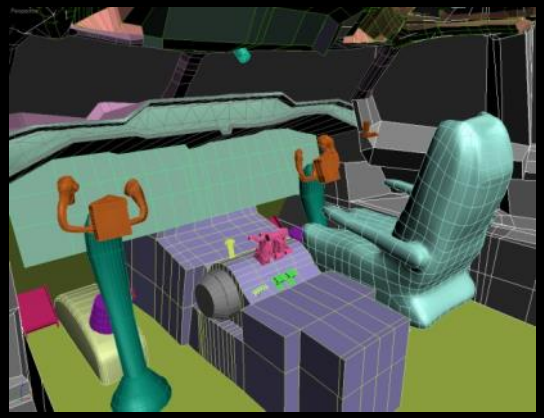
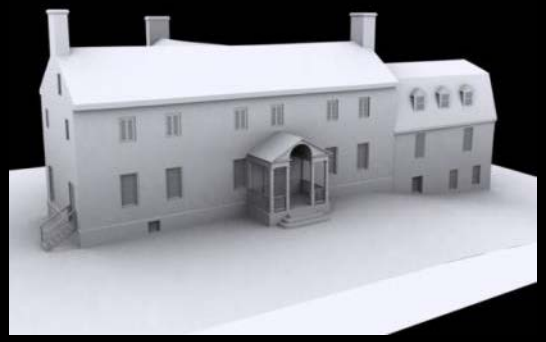
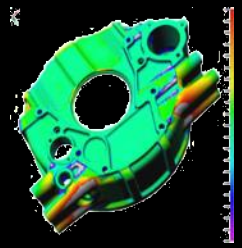


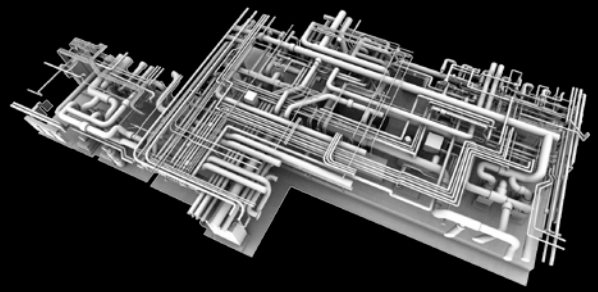




Methods, Tools, and Applications for Industrial Reverse Engineering of Legacy Parts



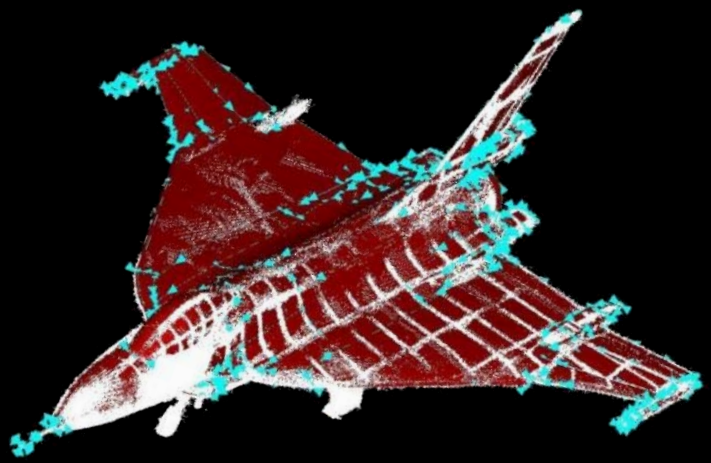
Michael Raphael
President & Chief Engineer
Direct Dimensions, Inc.
Baltimore, Maryland

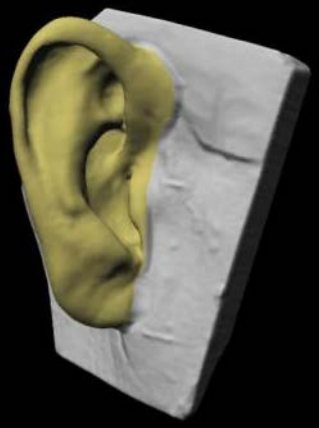


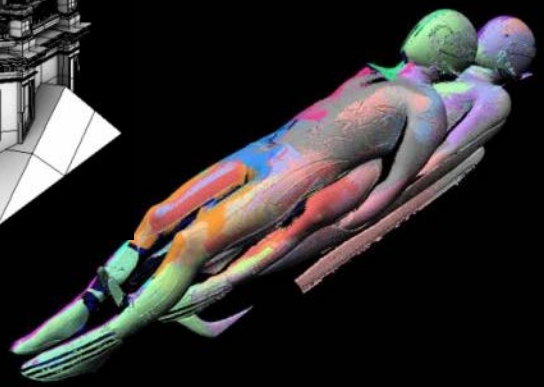
DIRECT DIMENSIONS
RAPID SOLUTIONS TO 3D PROBLEMS

Company Profile

Direct Dimensions is dedicated to tackling the most difficult challenges with the most advanced 3D technologies available. Direct Dimensions' staff has the tools and experience to provide optimal solutions for any scale, from microns to meters.







DIRECT DIMENSIONS
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Staff

Direct Dimensions scanning technicians have worked in every environment from jungle to city center to boiler-room basements using a variety of scanning and digitizing platforms.

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Services

Direct Dimensions provides a wide variety of services:

- Laser Scanning
- Digitizing
- Reverse Engineering
- Digital Modeling
- Inspection Analysis
- Replication
- Visualizations & Animations
- Product Representation & Sales
- Training and Support

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Products

Direct Dimensions is also a re-seller of a range of 3D solutions:

Scanners/Digitizers

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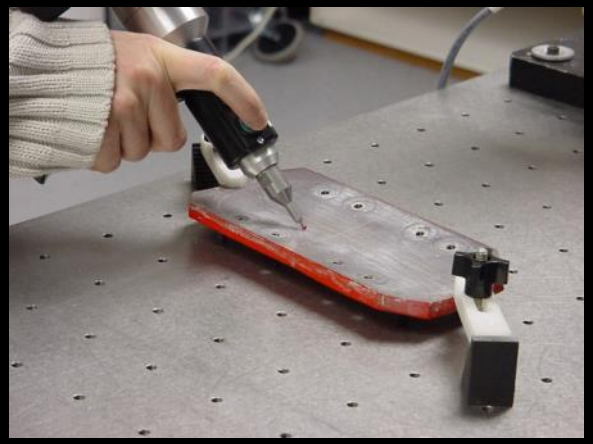
Digitizers

Portable Arm Probes



- Range = 0 to 2 meters
- Accuracy = +/- .024 mm
- Ideal Applications
  - Automotive Parts
  - Aerospace Parts
  - Power Generation
  - “Geometric” Shapes

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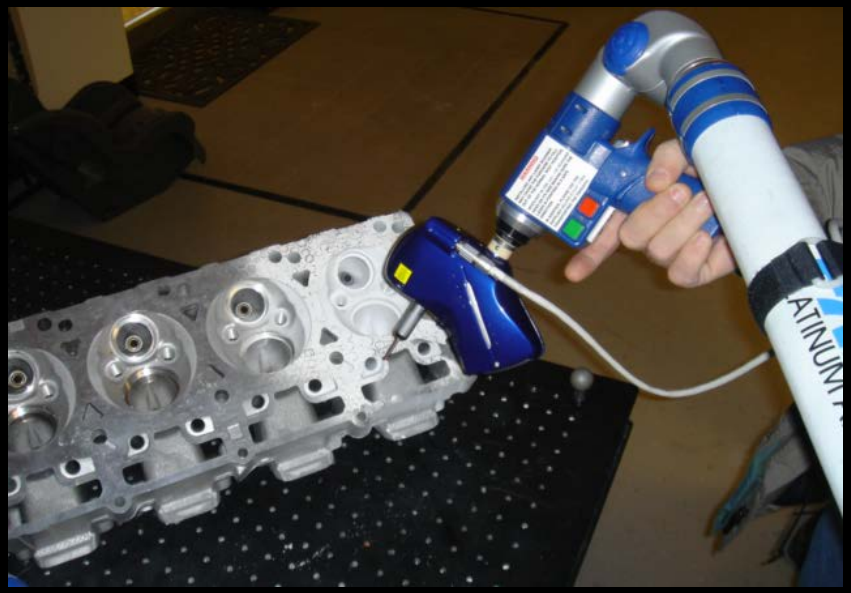
Laser Scanners

Portable Arm Scanners



- Range = 0 to 2 meters
- Accuracy = +/- .035 mm
- Ideal Applications
  - Dimensional Analysis
  - Cad-based Inspection
  - Alignment
  - “Organic” Surfaces
  - Reverse Engineering

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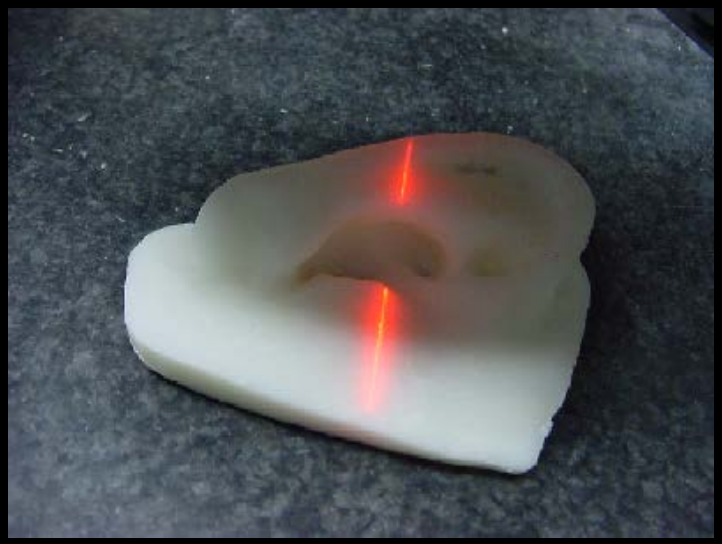
Laser Scanners

CMM

Coordinate Measure Machine



- Range = 0 to ? meters
- Accuracy = +/- .02 mm
- Ideal Applications
  - Dimensional Analysis
  - Cad-based Inspection
  - Alignment
  - Reverse Engineering
  - * Must fit in the machine

3D Scanner

Structured Light

- Range = .6 to 2 meters
- Accuracy = as low as .005 mm
- Ideal Applications
  - Small area inspection
  - Miniature sculpture
  - Intricate parts

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Laser Scanner

Patch Scanners

- Range = .5 to 5 meters
- Accuracy = as low as .04 mm
- Ideal Applications
  - Sculpture
  - Face/Body
  - Vehicle parts

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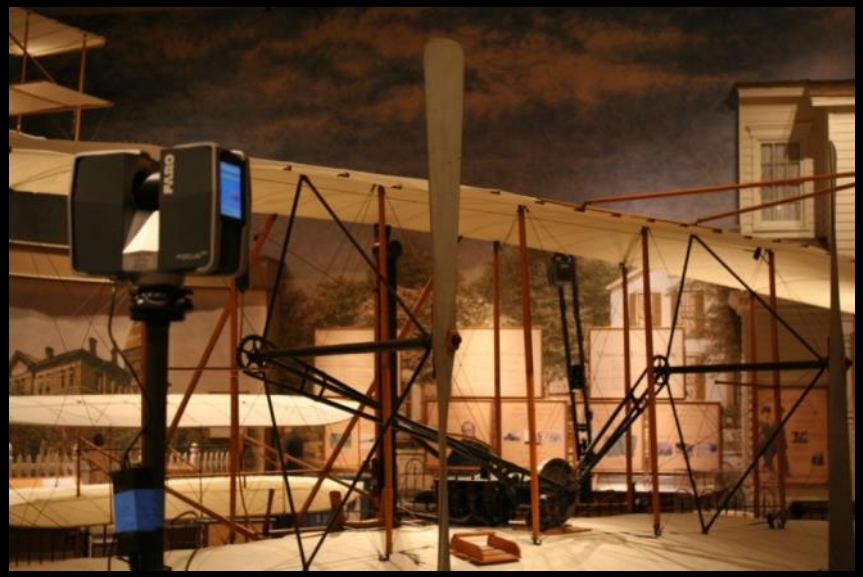
Hemispherical Scanners

Phase-Based

- Range = .5 to 120 meters
- Accuracy = as low as 1 mm
- Ideal Applications
  - Buildings
  - Vehicles
  - Large Sculpture
  - Bridges
  - “Overall” scans

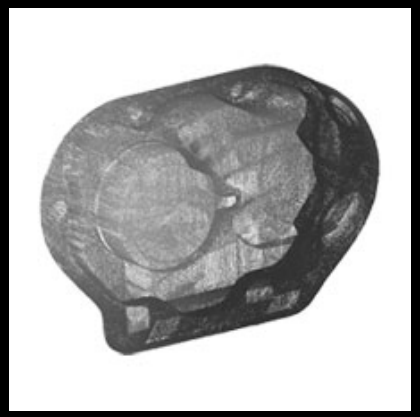


DIRECT DIMENSIONS

Reverse Engineering

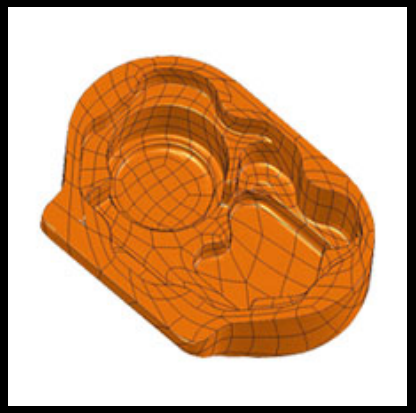
CAD Modeling

Point Cloud

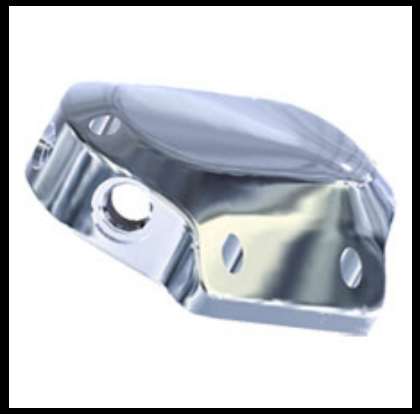


Polygon Mesh

Rapid NURBS



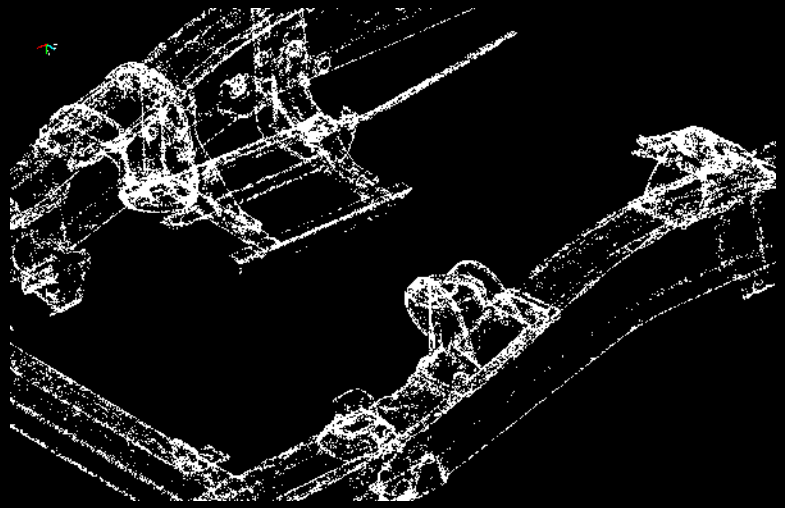
Hybrid Model

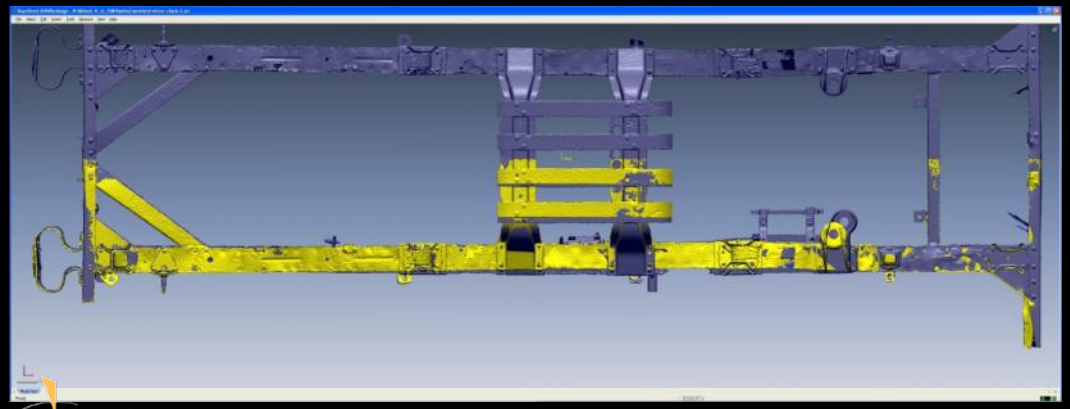


Engineered Solid Model

Engineered Surface Model

Overview of the Solution: Jeep Frame Case Study





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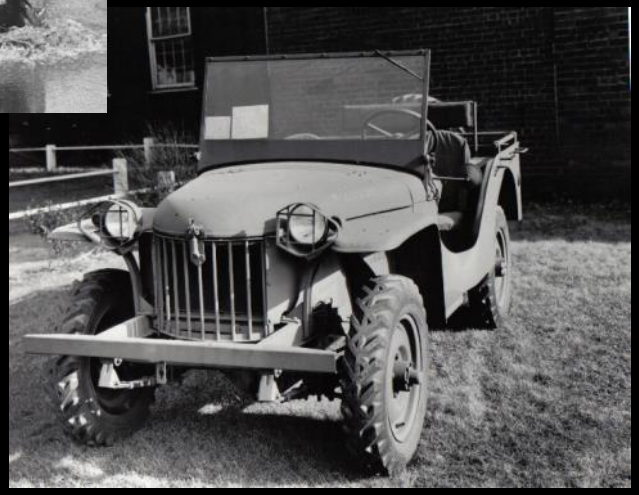
Historical Overview of the Jeep

- Original “Jeep” Prototype
- 1940 American Bantam Car Company pilot model



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Specific Client Request

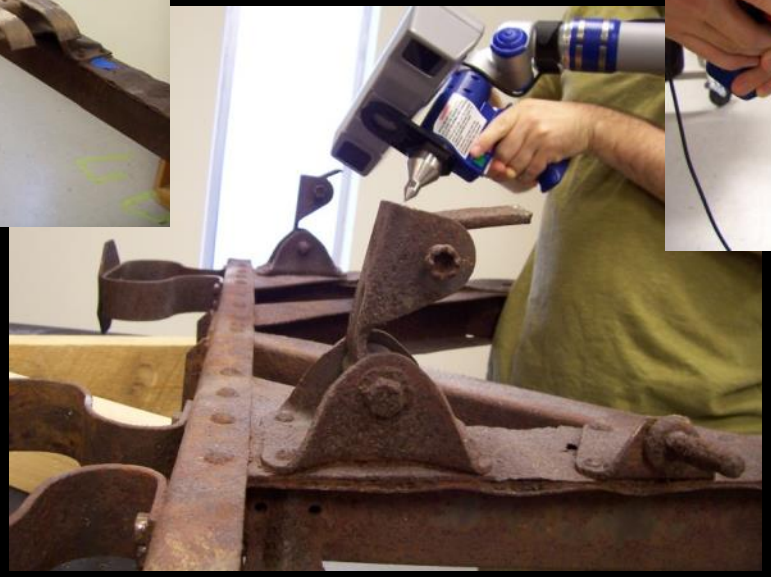
- Measure various parts from antique BRC-40 Jeep frame
- Parts needed to be completed in an AutoCAD format
- Accurate models needed so client can duplicate them exactly
- Specific parts include: frame rails, spring mounts, and “K” cross member

Identifying the Problem

- Original deteriorating frame posed measurement problems because of frame warping and corroded components
- “Design intent” model needed

Initial Step – Laser Scanning and Data Capture

- Scanning the Jeep frame with the LDI Laser Scanner



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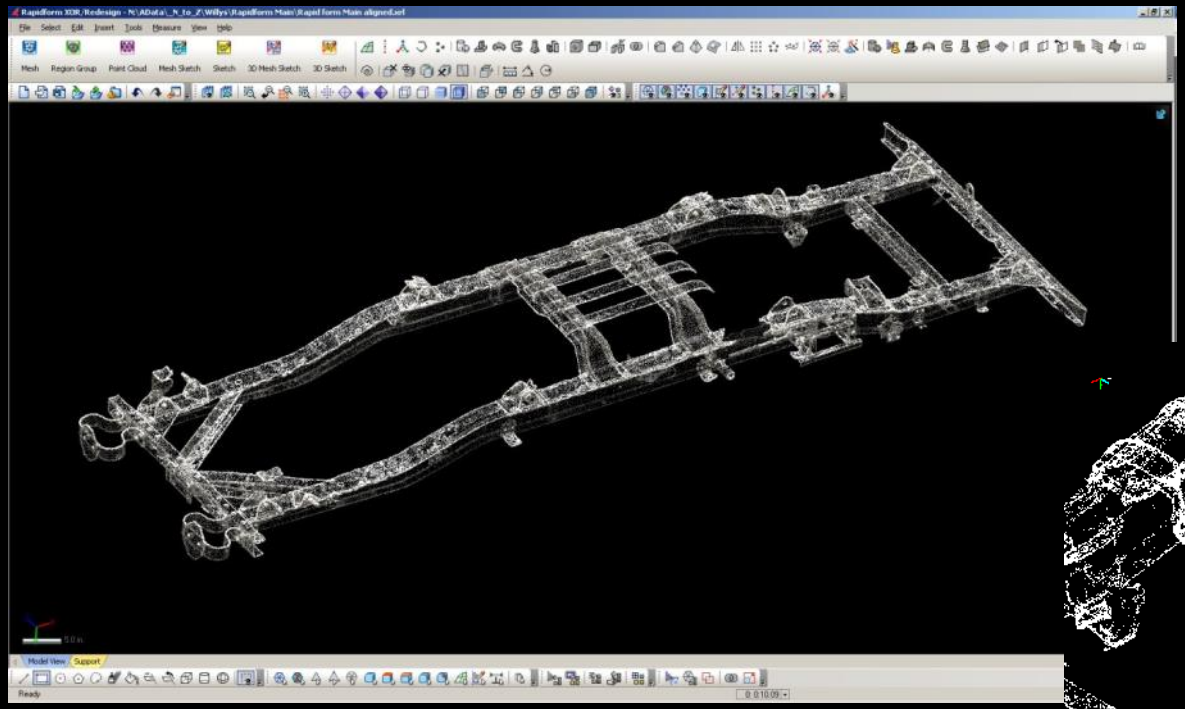
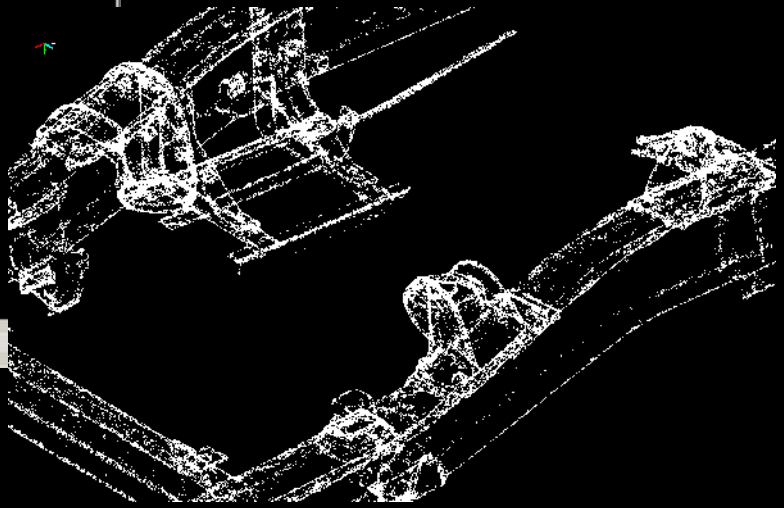
Next Step –Aligning Point Clouds

- Aligning the captured point clouds in RapidForm





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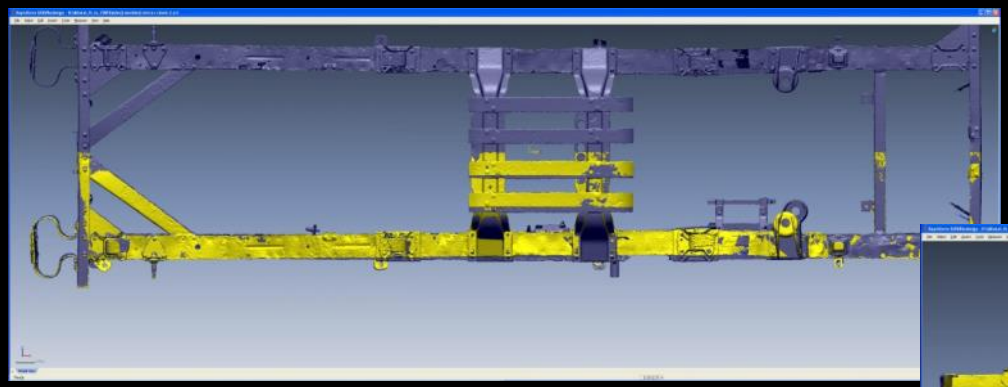
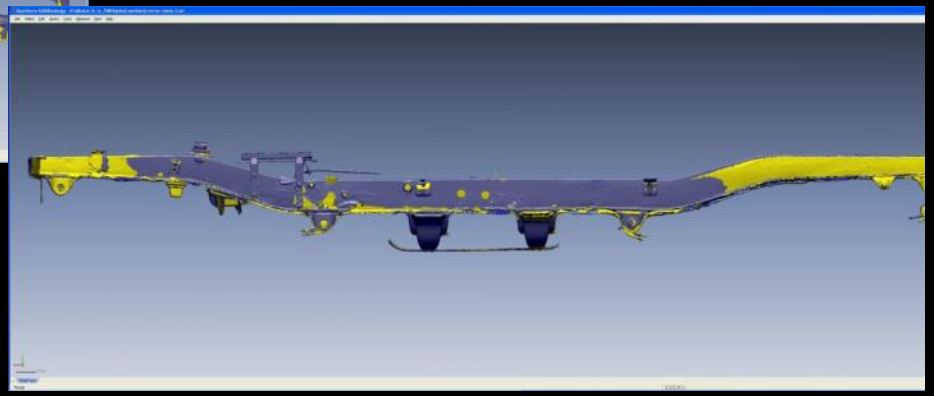
Next Step – Mirroring Frame

- Mirroring and Comparing one side of the frame to the other





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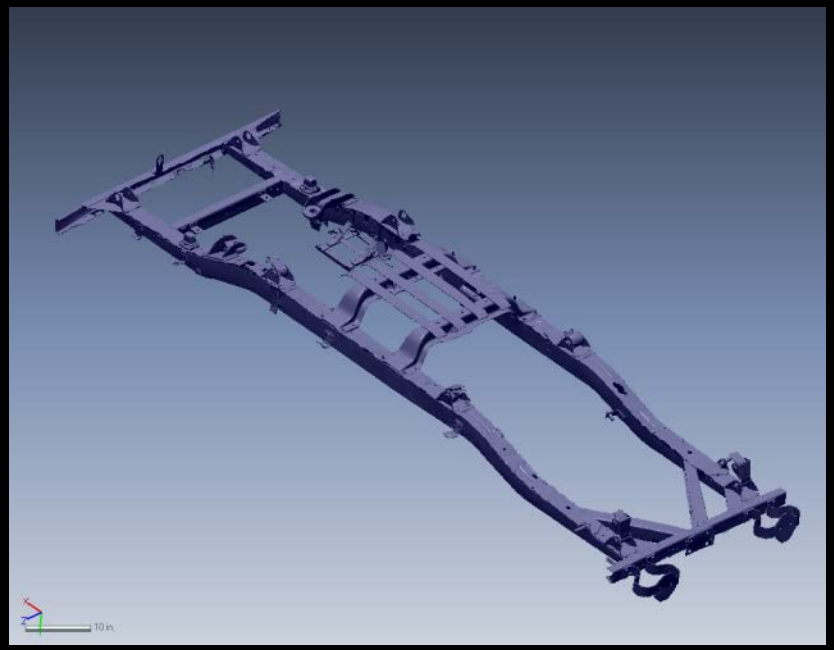
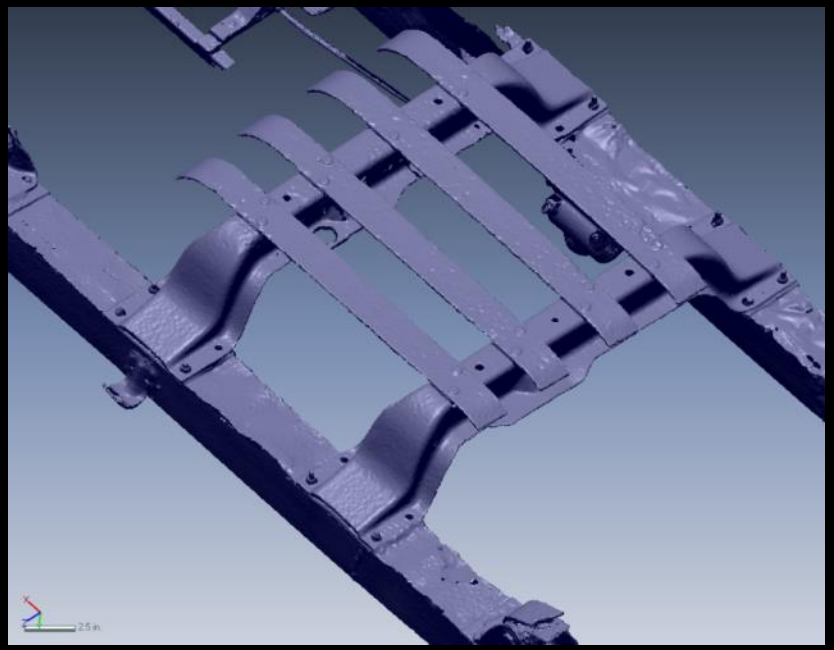
Next Step – Polygonal Modeling

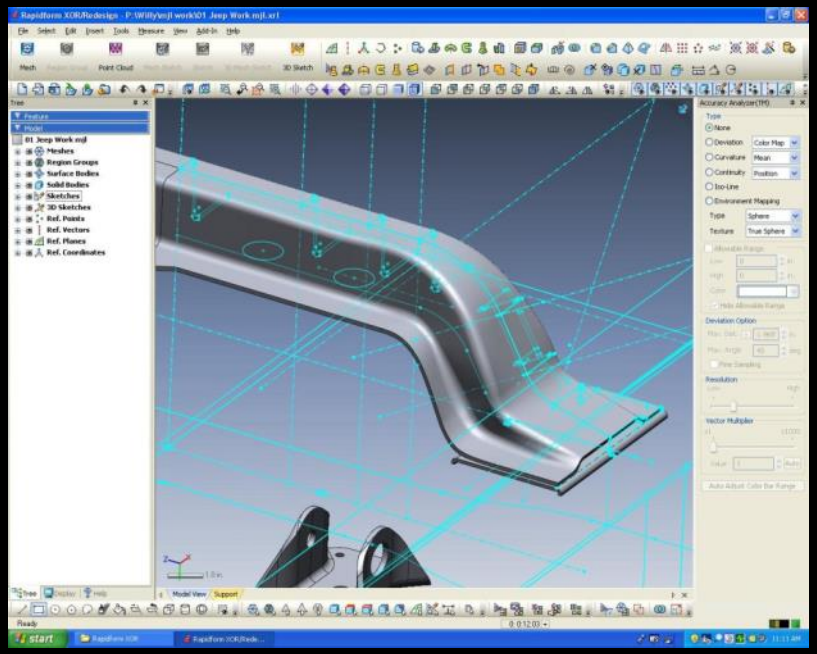
- Aligning, cleaning, and filling in holes on the polygonal model

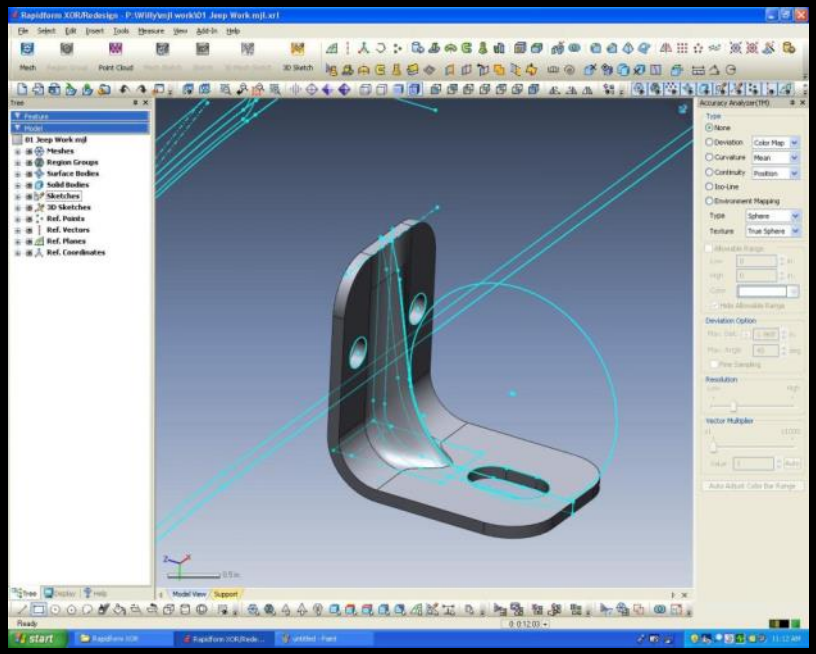




Next Step – Reverse Engineering Specific Parts

- Aligning part positions to hole locations and other features





Next Step – Reverse Engineering Specific Parts

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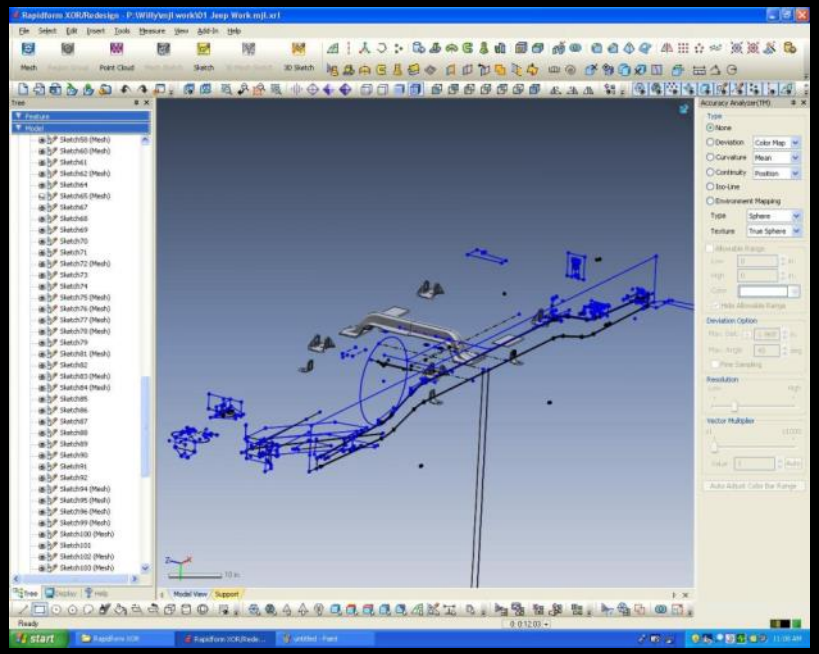
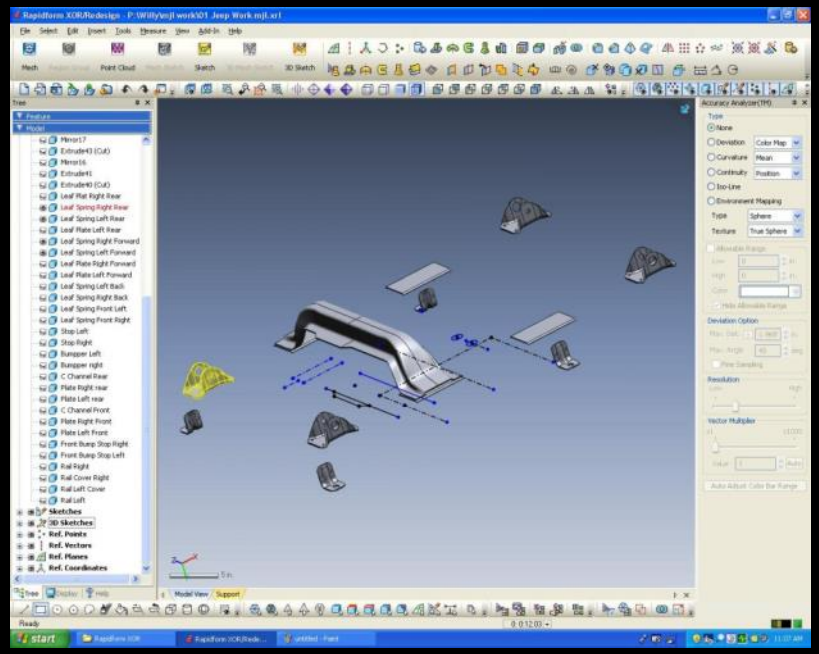
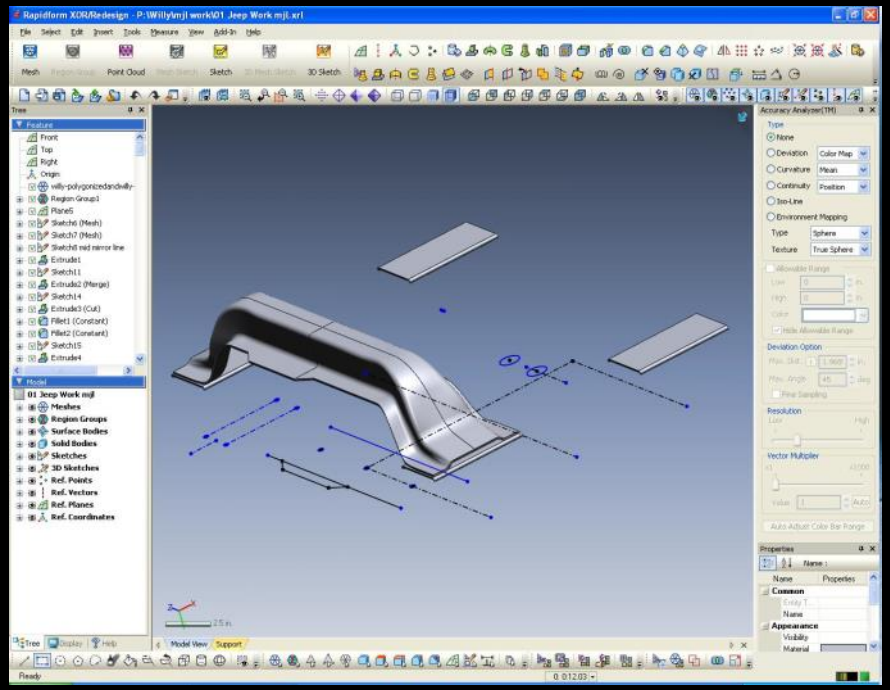
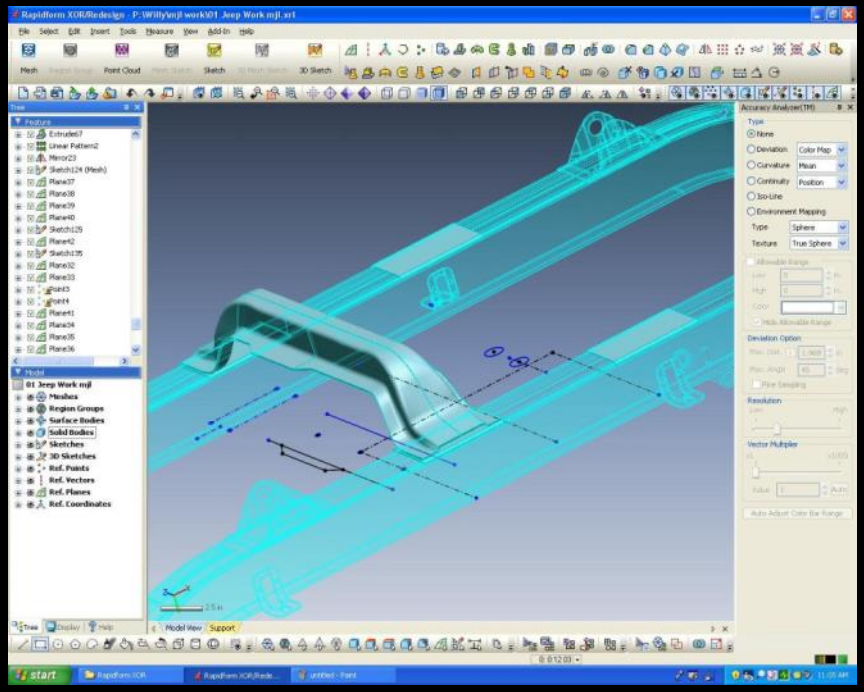




Next Step – Reverse Engineering Specific Parts

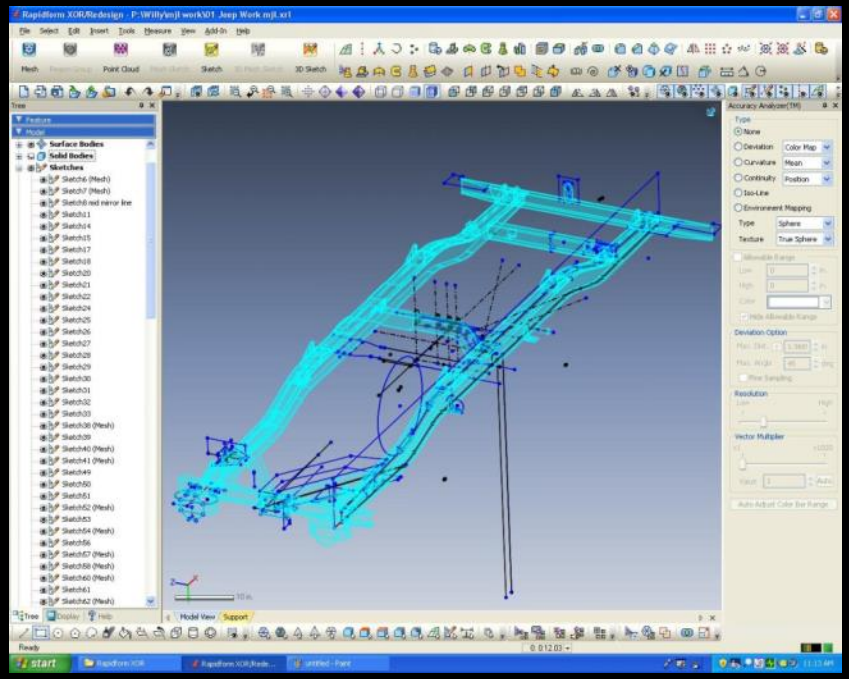
- Reverse Engineering and creating specific features from the polygonal and geometric data

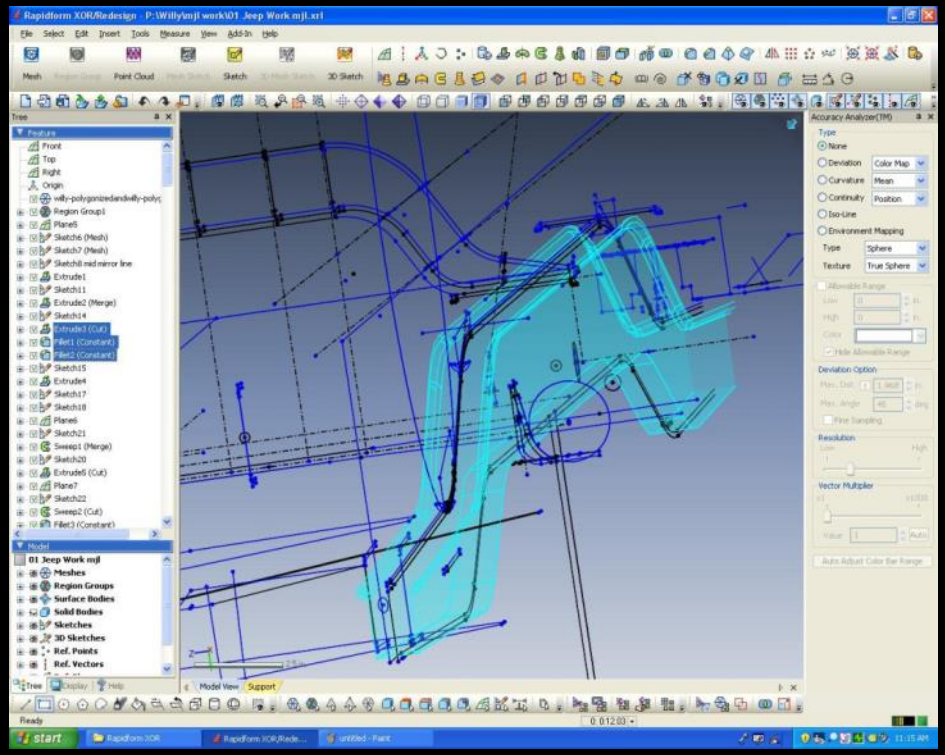




Next Step – Reverse Engineering Specific Parts

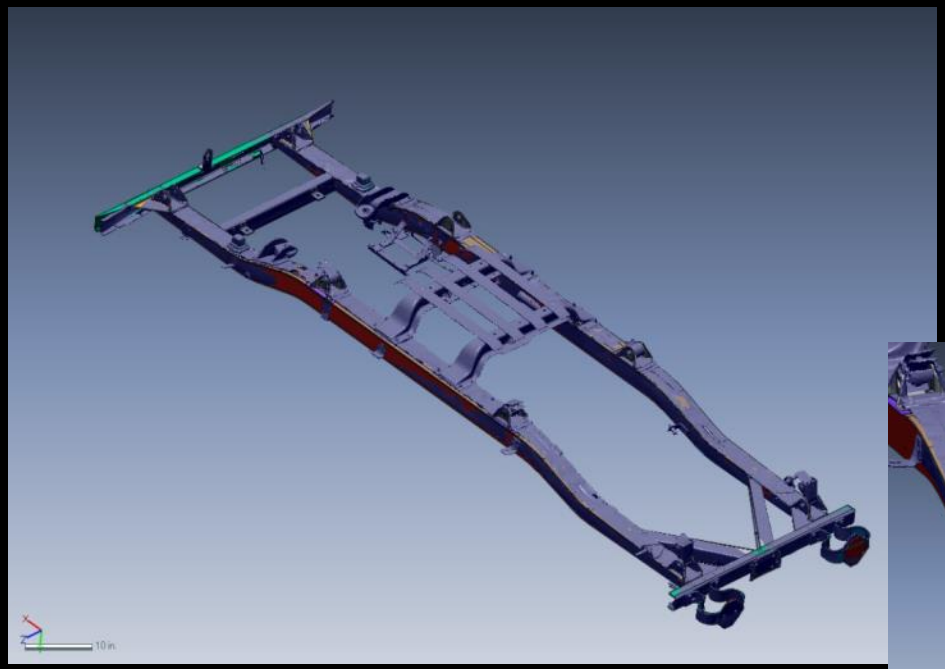
- Continuing to create and align specific parts to the overall rail form

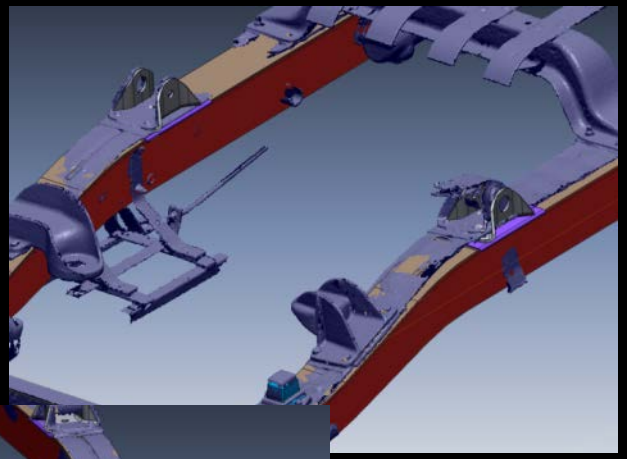


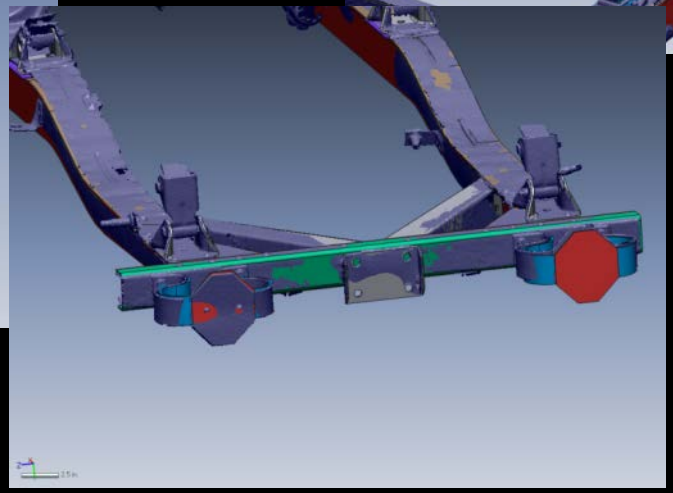


Next Step – Comparing Captured Polygonal Model to "Design Intent"

- Overlaying the "Design Intent" model on top of the completed polygonal model to check for error and inconsistencies







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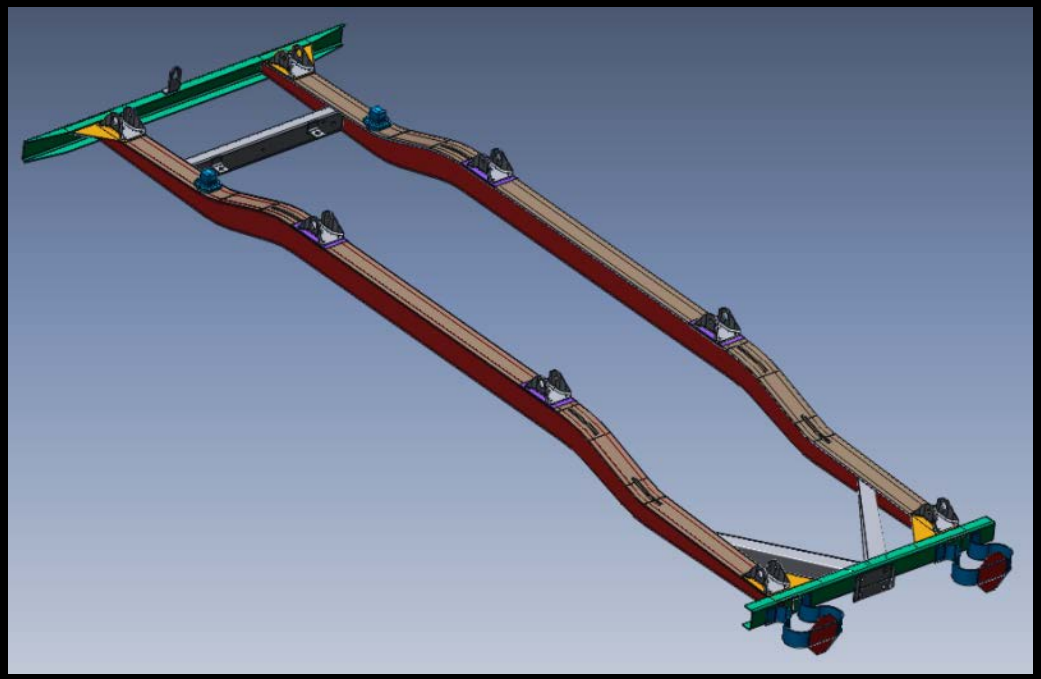
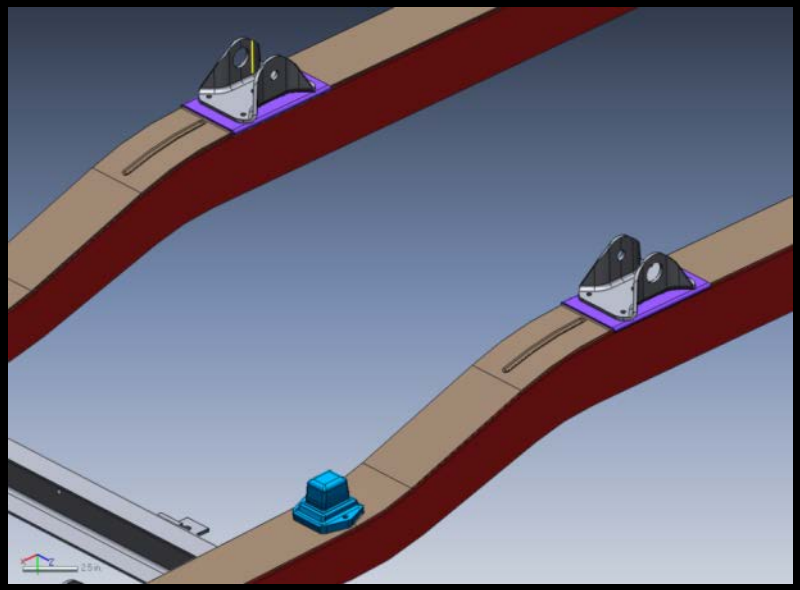
Final Step – Deliver Requested Models

- Complete all modeling and deliver the requested models in proper formats



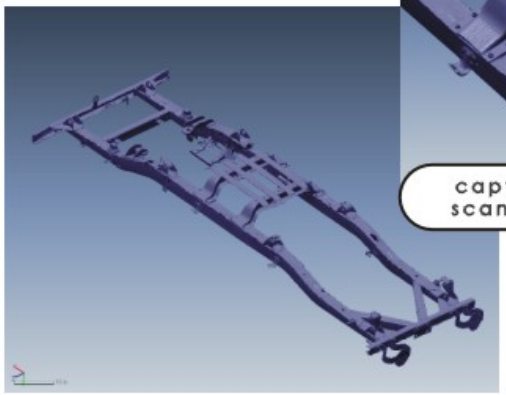


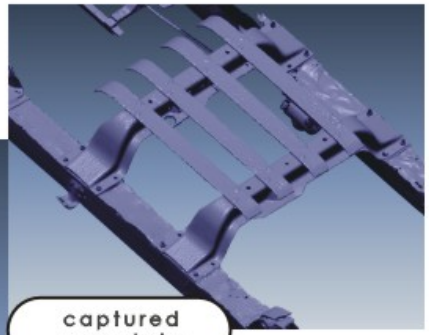
jeep frame

REPRODUCTION

DDI used the LDI Scanner on a 12' FARO Arm to capture an antique jeep frame. The main structure of this corroded and warped frame was reverse engineered to produce an accurate design intent model. This new solid model can now be used to manufacture new jeep parts.

laser scanning jeep frame

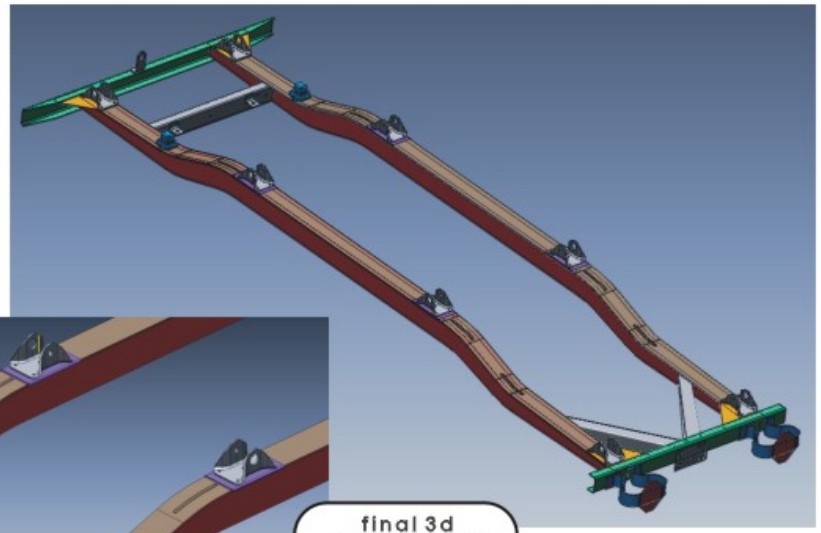


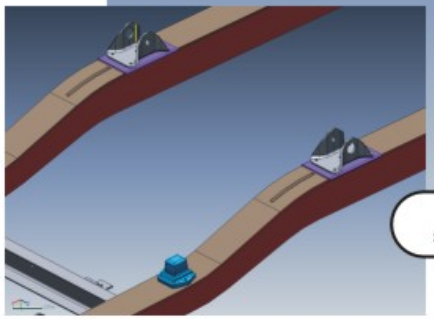


captured scan data

original jeep frame

frame rust detail





final 3d solid model

DIRECT dimensions

rapid solutions to 3D problems...

www.directdimensions.com

Methods, Tools, and Applications for Industrial Reverse Engineering of Legacy Parts

Michael Raphael

President & Chief Engineer

Direct Dimensions, Inc.

Baltimore, Maryland

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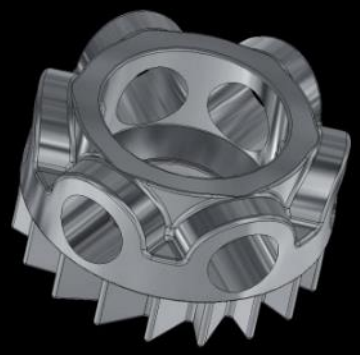
mraphael@dirdim.com



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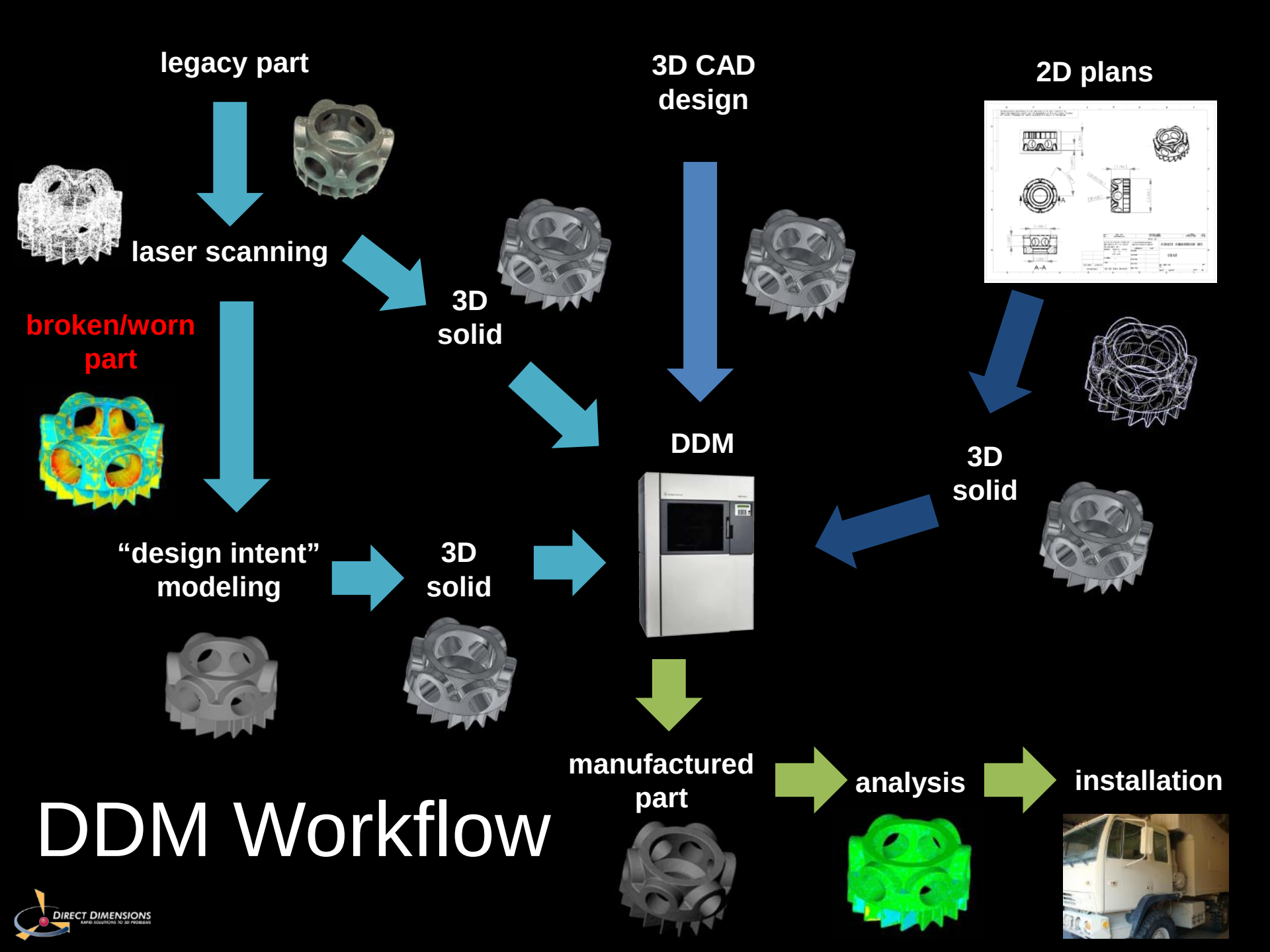
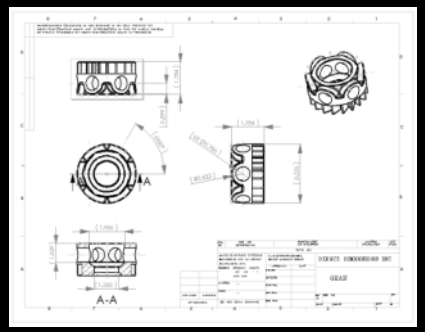
BACKUP Slides


legacy part
3D CAD design
2D plans
laser scanning
3D solid
broken/worn part
DDM
3D solid
"design intent" modeling
3D solid
manufactured part
analysis
installation
DDM Workflow
DIRECT DIMENSIONS

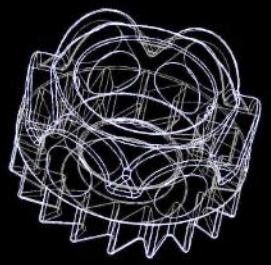
DDM Workflow

2D-3D CAD Migration

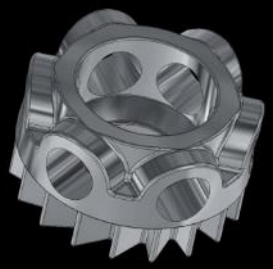
2D Plans



3D wireframe



3D Solid



Manufacture

DIRECT DIMENSIONS
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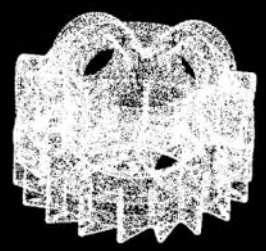
DDM Workflow

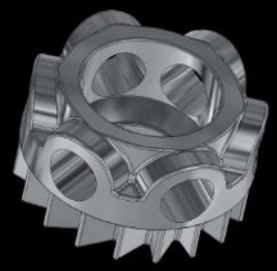
Legacy Part - No Plans

Legacy Part

Laser Scan Point Cloud



3D Solid



Manufacture

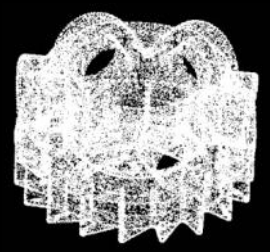
DIRECT DIMENSIONS
RAPID SOLUTIONS TO 3D PROBLEMS

DDM Workflow

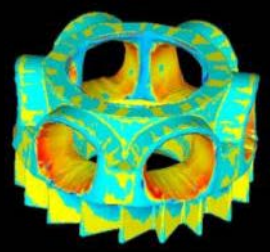
Legacy Part - No Plans - Worn/Broken

Legacy Part

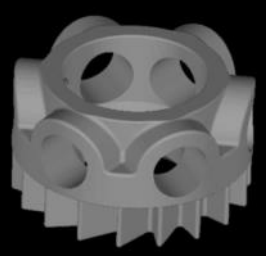
Laser Scan Point Cloud



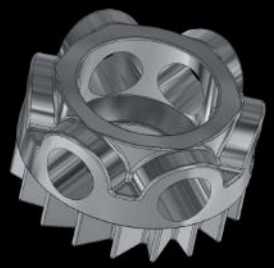
Worn/ Broken



"Design Intent"



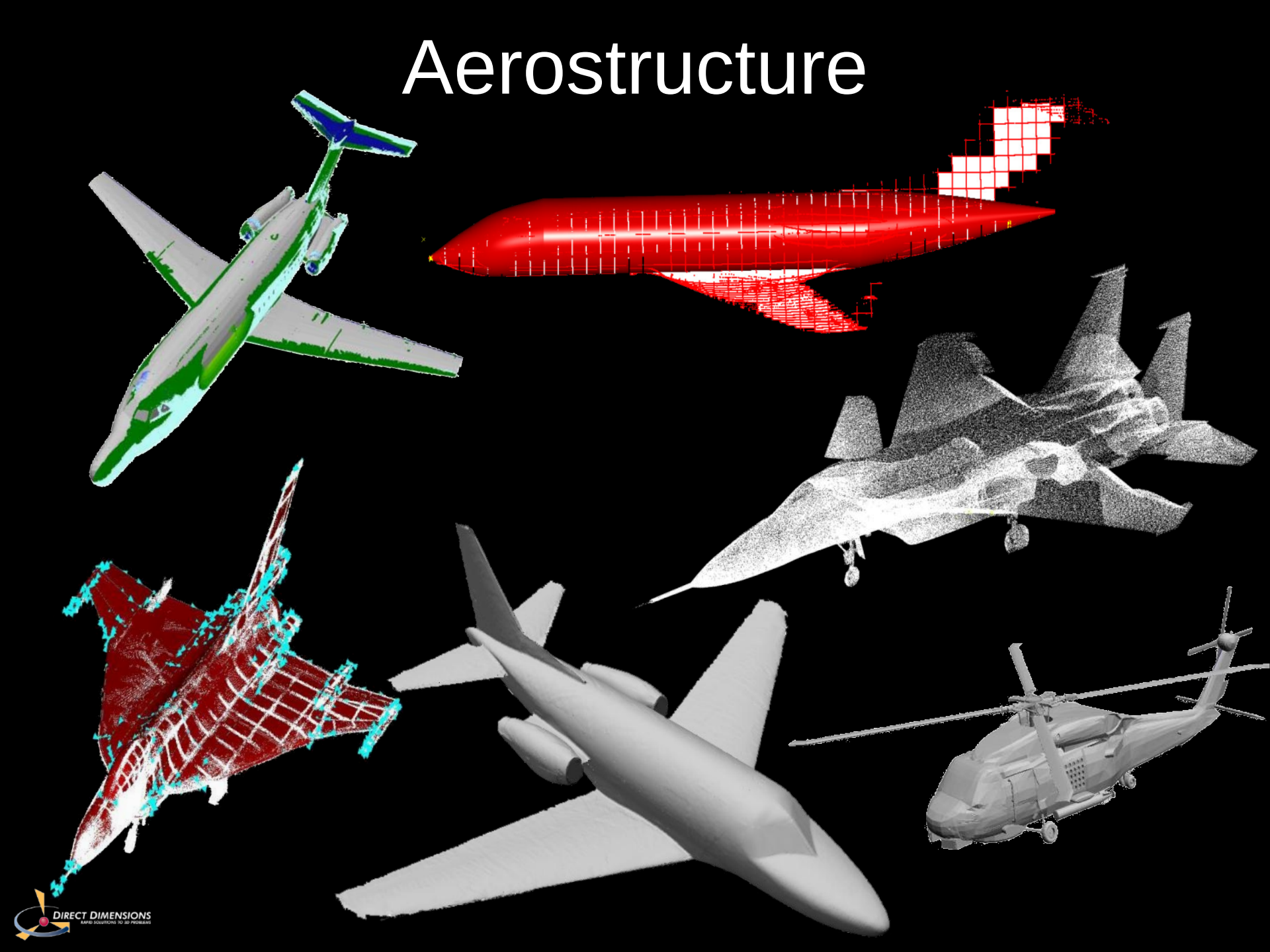
3D Solid



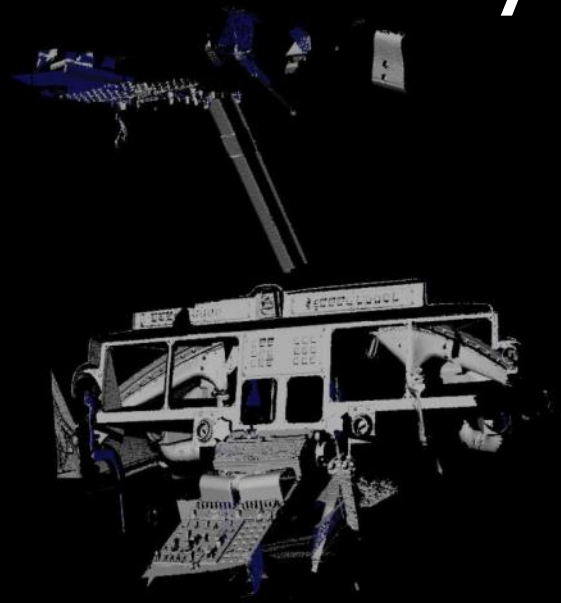
Manufacture

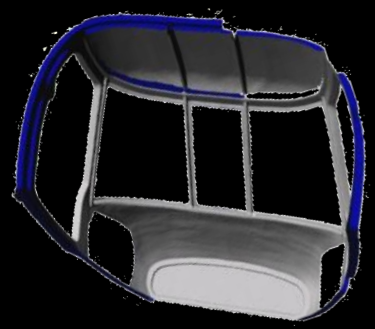
DIRECT DIMENSIONS
RAPID SOLUTIONS TO 3D PROBLEMS

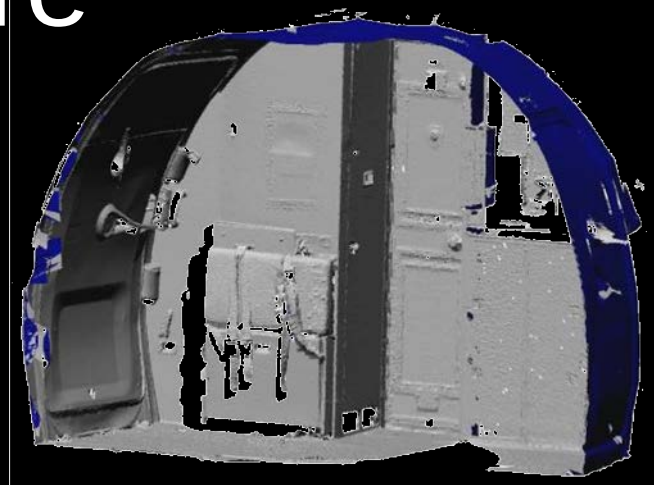
Aerostructure

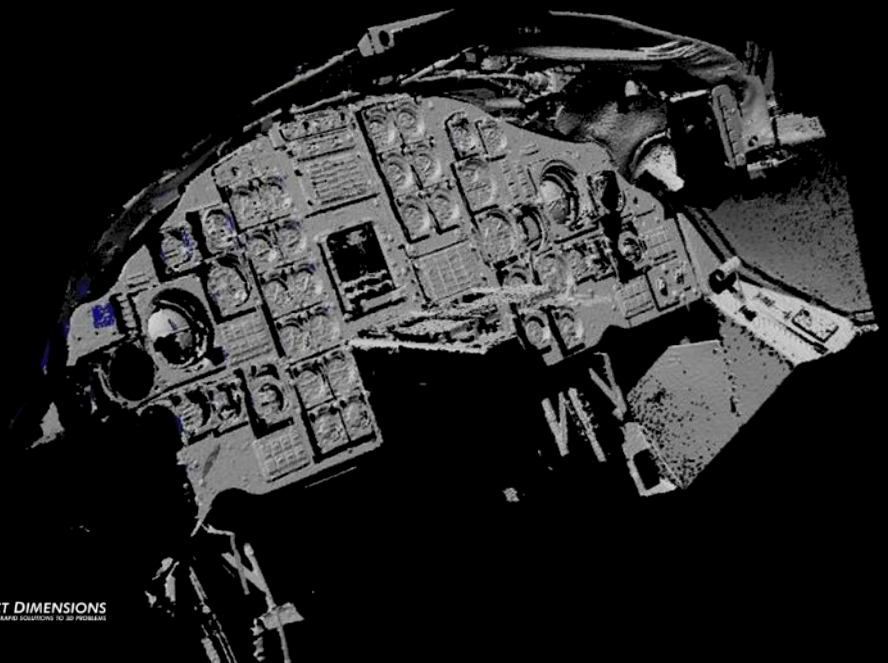


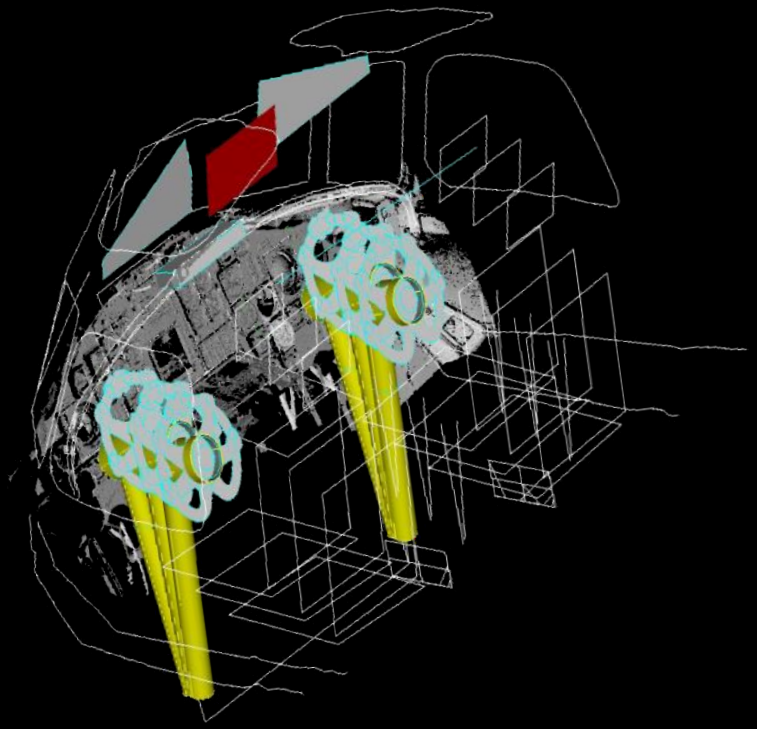
Aerostructure











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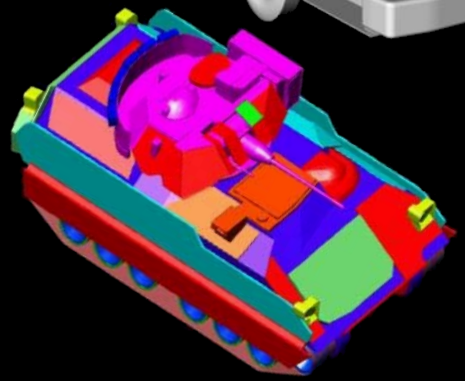
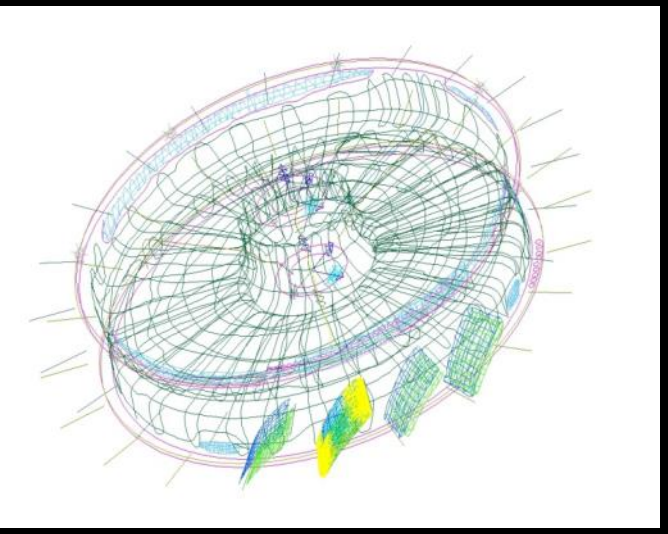
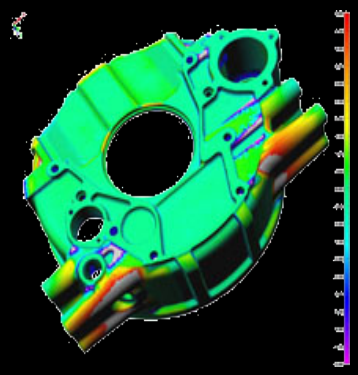
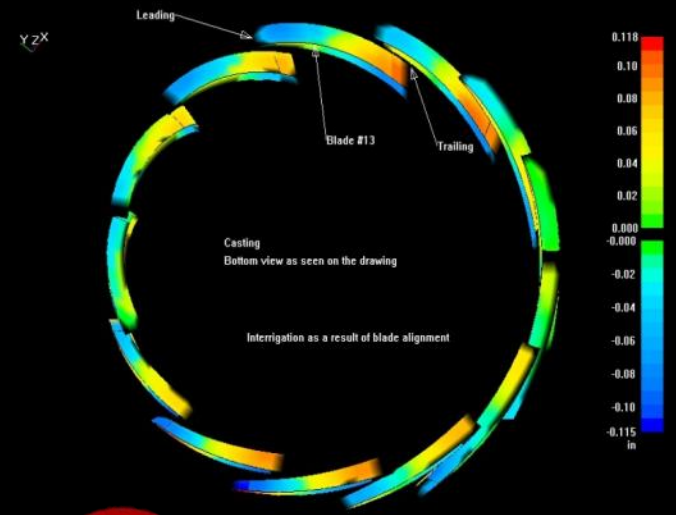
Automotive

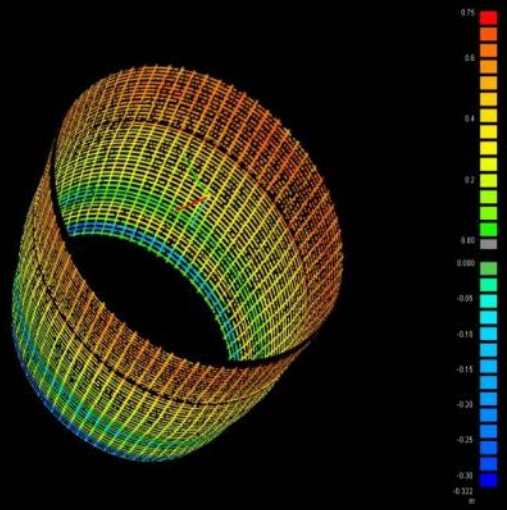


Mechanical Design









DIRECT DIMENSIONS
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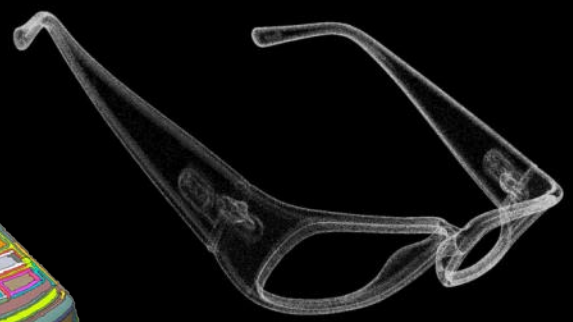
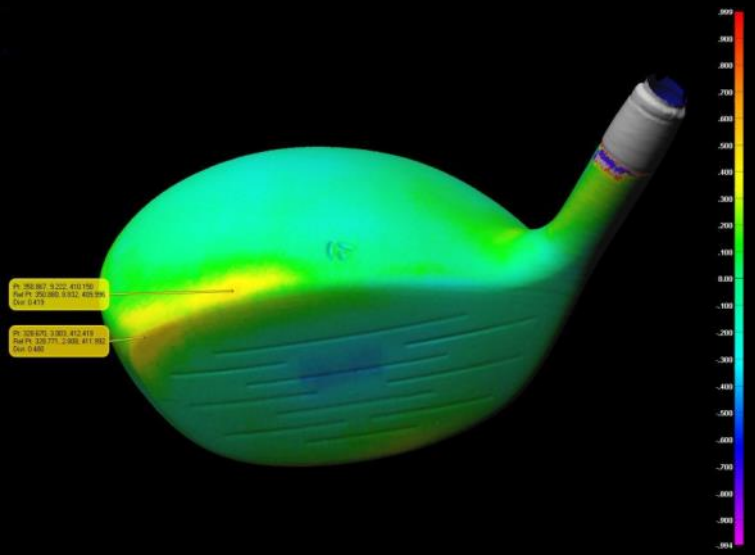
Consumer Products





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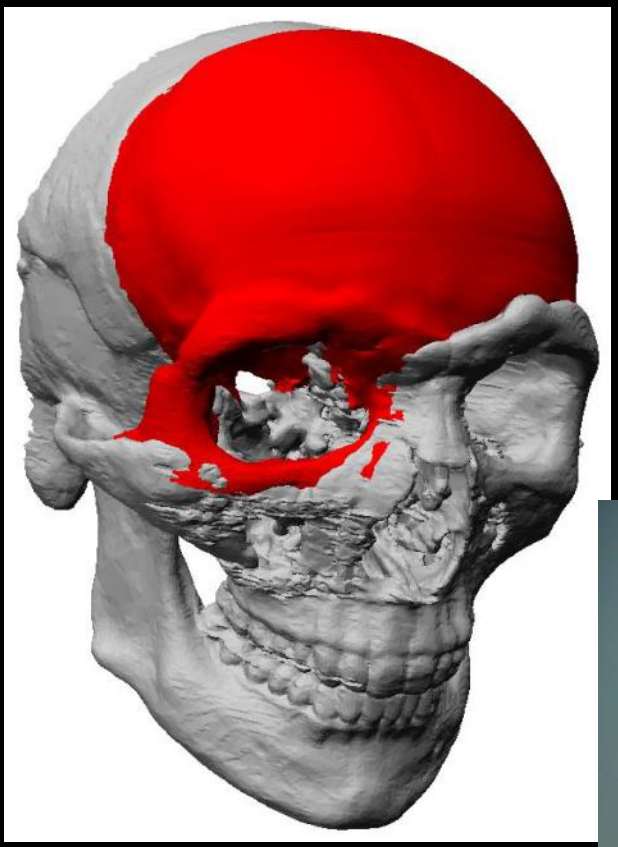
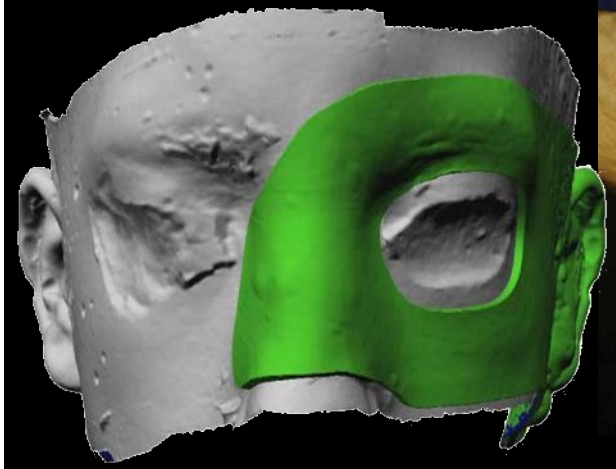
Custom Components

DIRECT DIMENSIONS
RAPID SOLUTIONS TO 3D PROBLEMS

Medical





DIRECT DIMENSIONS
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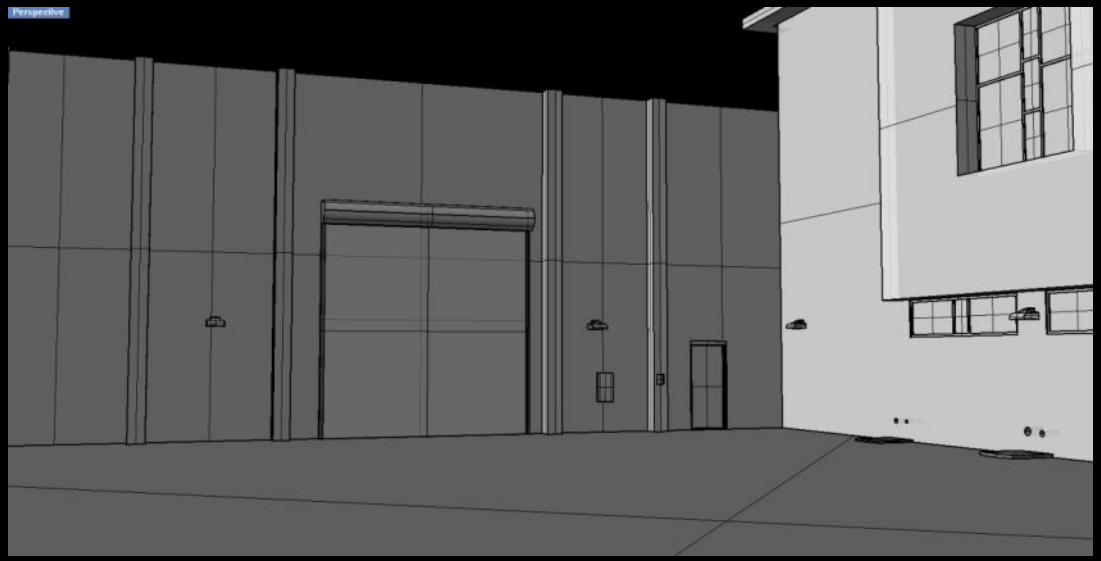
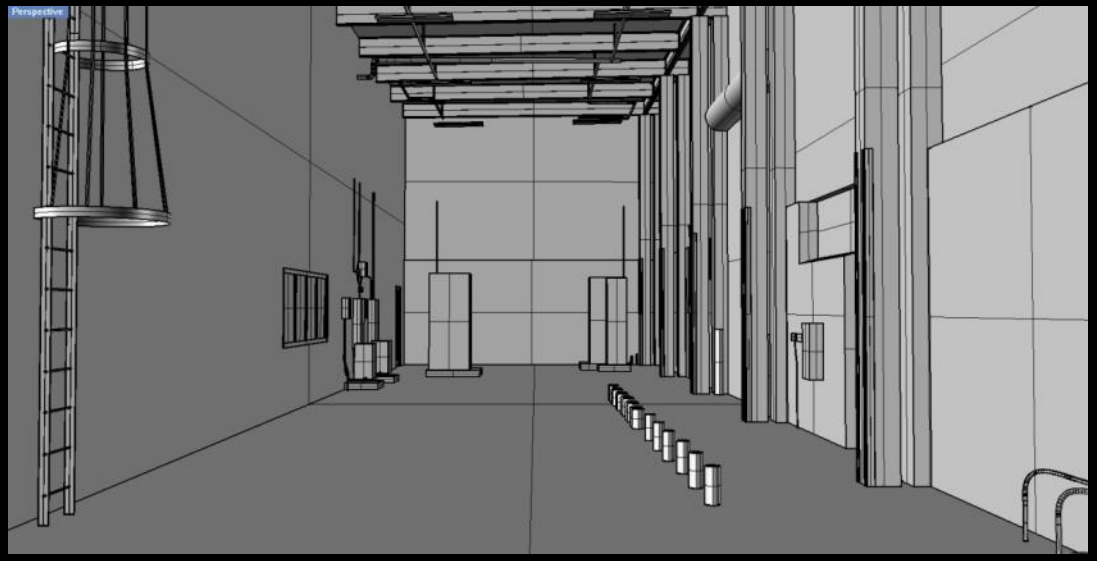
Facilities





DIRECT DIMENSIONS
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removed jeep frame process

hand GRIP

The grip shown was the last replacement part in the Navy's inventory. The manufacturer was out of business and no tooling or drawings existed. DDI precisely measured and modeled the part and an SLA was created for use as a pattern for a new casting.

raw scan data

Surfacing added

Texture added

FARO Arm measurements

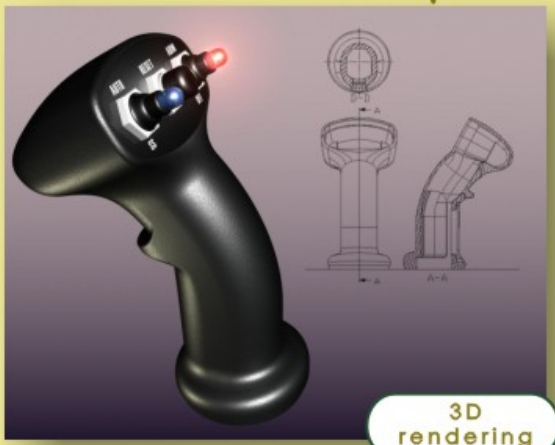
1

2

3

4

5



3D rendering

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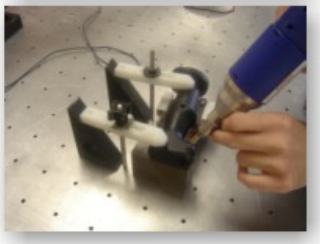
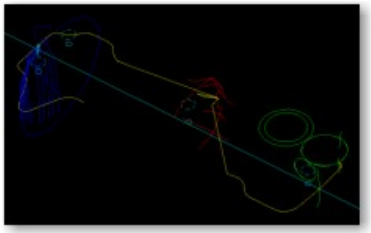
military
GRIP

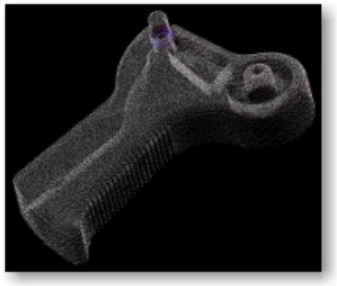
Problem:
More physical parts were needed to be manufactured at a low quantity.

Solution:
Using reverse engineering, DDI was able to deliver a clean parametric Solidworks cad model that could then be machined to create the necessary amount of parts.

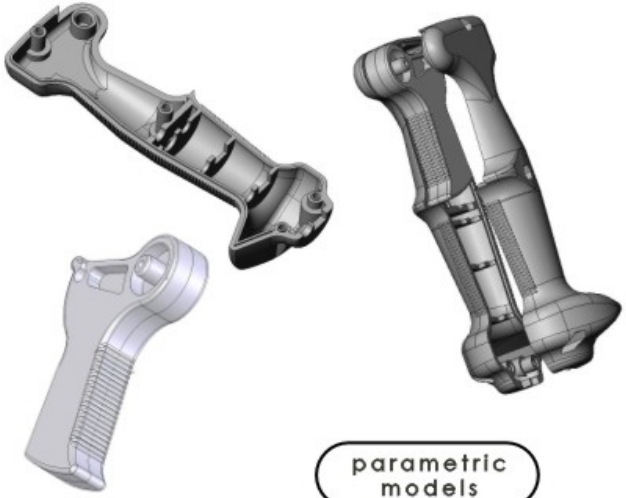


taking point data



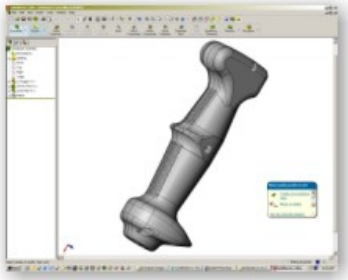


faro and point data



parametric models

original grip



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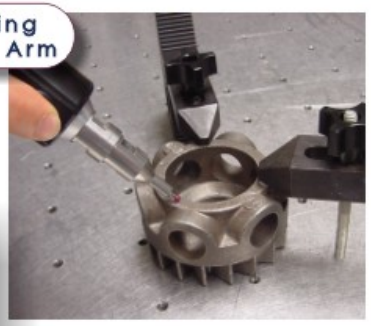
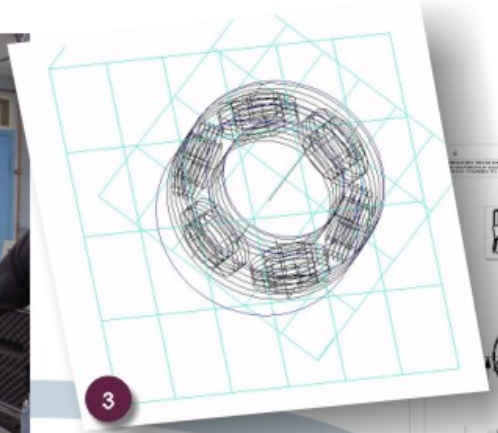
GEAR

Because no blueprints existed for the gear component, DDI was asked to reverse engineer the part. The Faro Arm was used to measure the features and the data was used to model the part as a solid and to create the drawing.

2

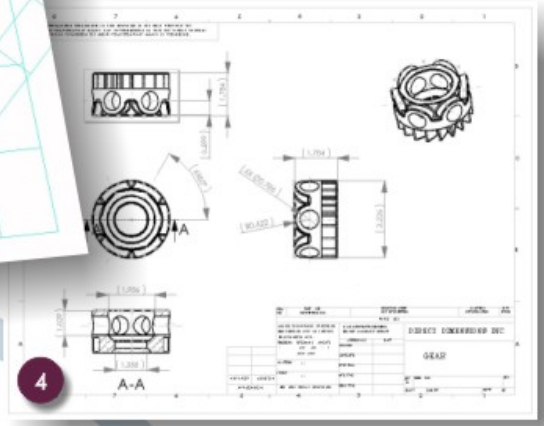
measuring by FARO Arm





3

extrapolated data



4

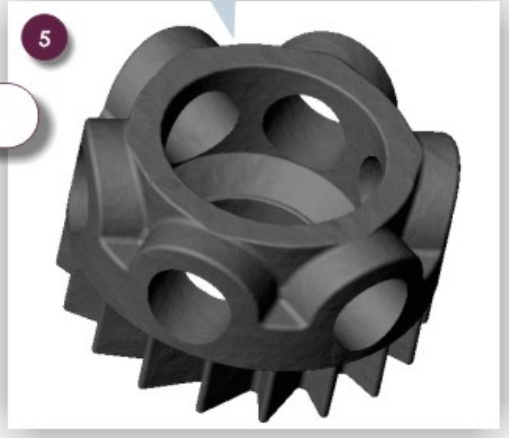
controlled drawing from data

1

original gear

5

rendered solid



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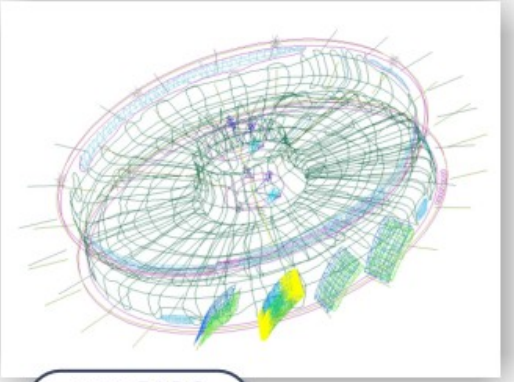
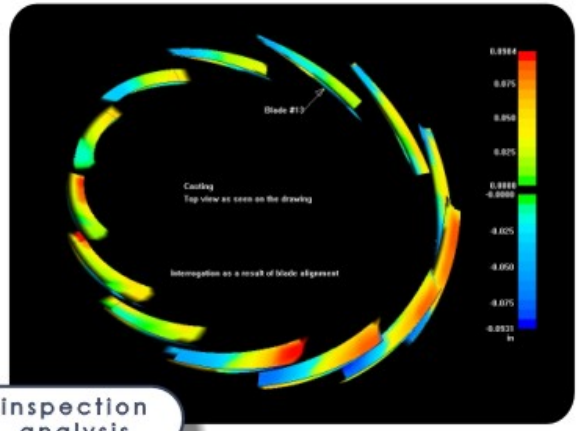
cast

ROTOR

The FARO Arm was used to digitize a critical component of a marine air handling system. The actual blade measurement data was compared to the nominal engineering design for location and contour accuracy.

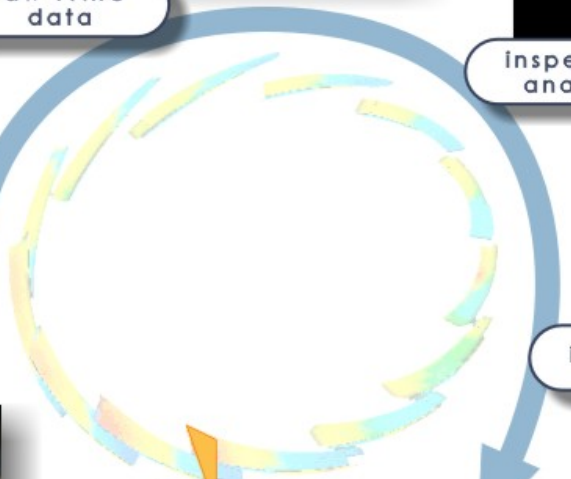


raw FARO data

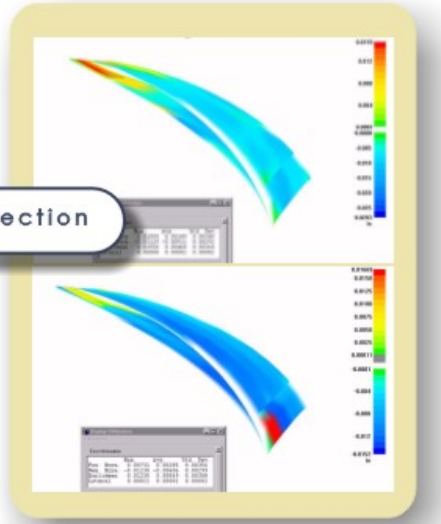


inspection analysis

original part



inspection



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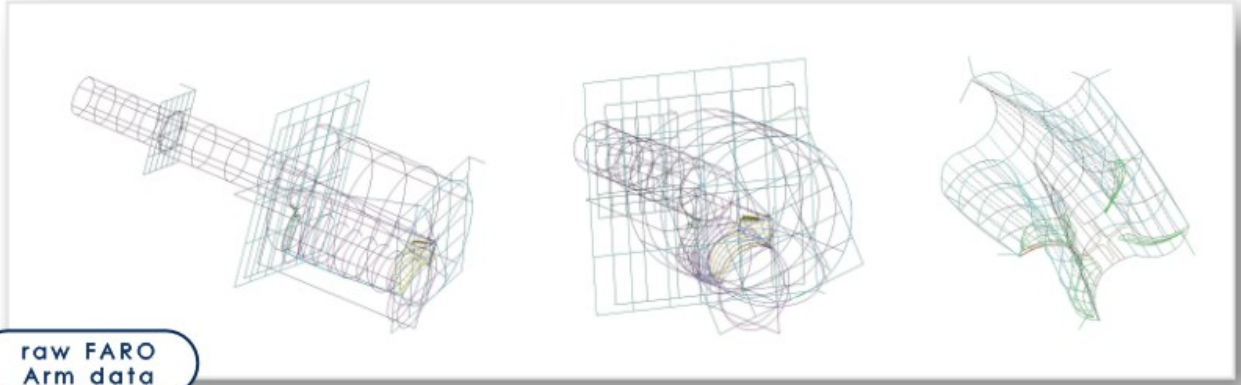
propellant

MIXER

An aged critical component of a propellant mixer for the Army needed replacing. No drawings or tooling existed. The FARO Arm was used to measure, a CAD model was created, and a rapid prototype was built. The RP model was used directly as a pattern for a new casting for the new part.



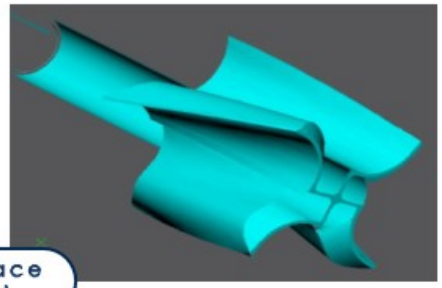
raw FARO Arm data

original component

1

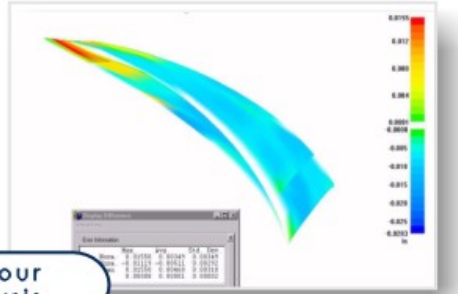
2

3



3D surface model

4



contour analysis

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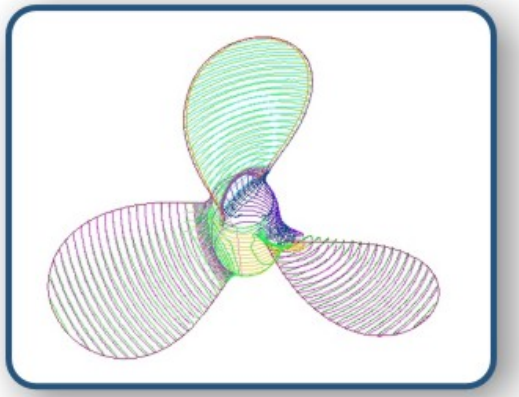
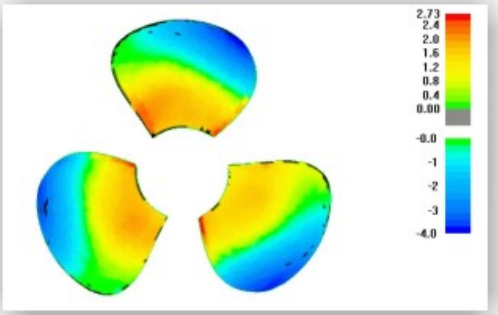
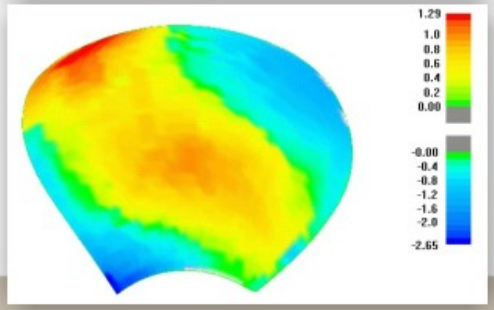
PROPELLERS

The FARO Arm is an excellent device for measuring the pitch and complex contour of marine propellers. The software provides for circular cross-section scanning for proper pitch analysis.

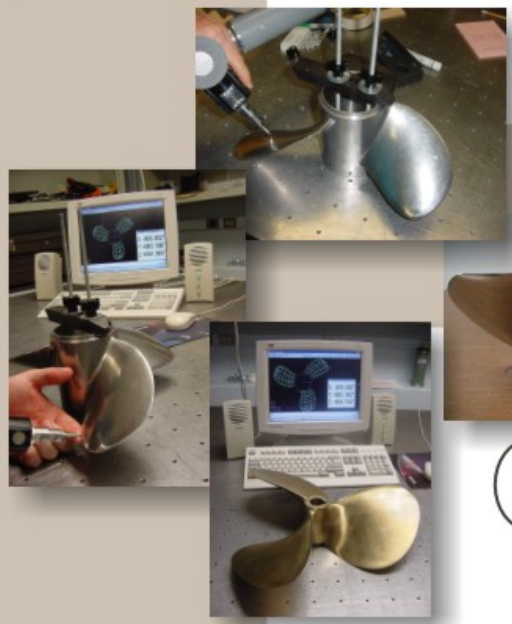


FARO data

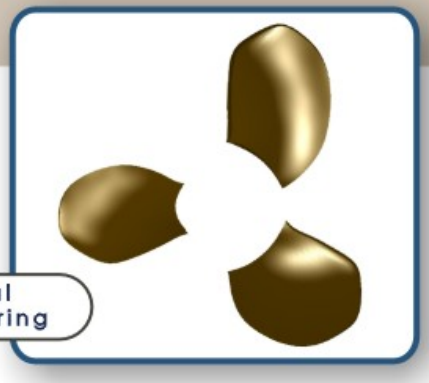




inspection charts



propellers scanned by FARO Arm



final rendering

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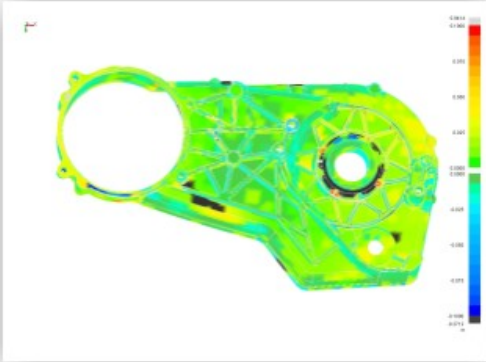
large industrial

CASTING

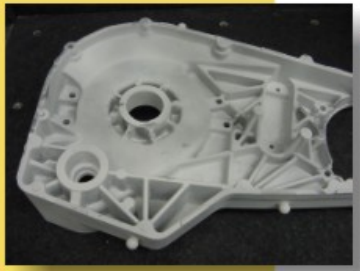
Advanced inspection and analysis tools simplify the dimensional verification of this complex cast part. The laser quickly scans the surfaces without contact and creates an accurate point cloud. The ense cloud is then compared to the nominal engineering CAD model and the results are displayed in easy to understand color graphical images.

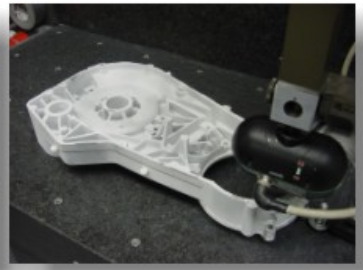
raw point data

nominal CAD model



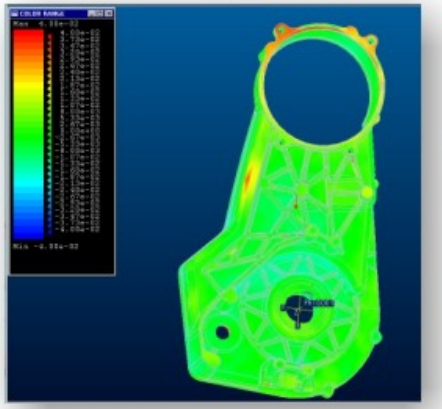
color inspection analysis





original casting scanned by Kreon

Image from Pro/Verify



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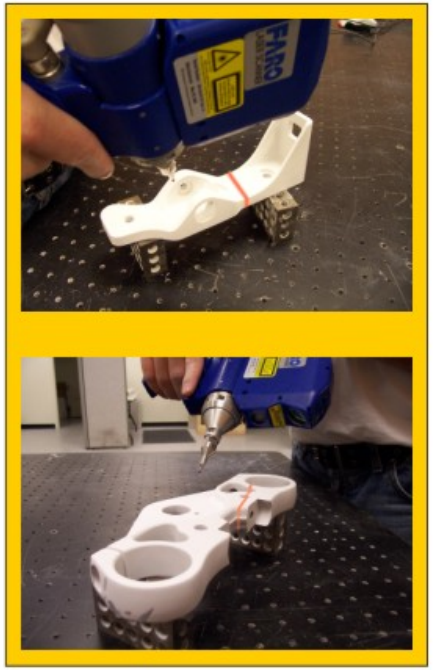
motorcycle

BRACKET

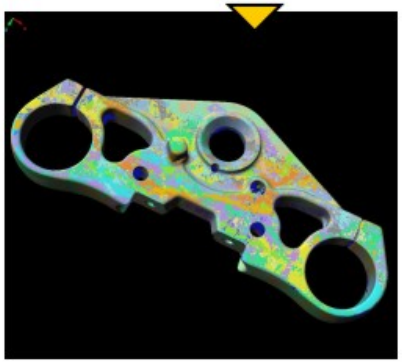
As a demonstration, DDI laser scanned and modeled motorcycle brake brackets in order to complete an inspection of the parts. Using the captured 3D data, DDI was able to accurately show where the actual parts were different from the supplied CAD reference models.



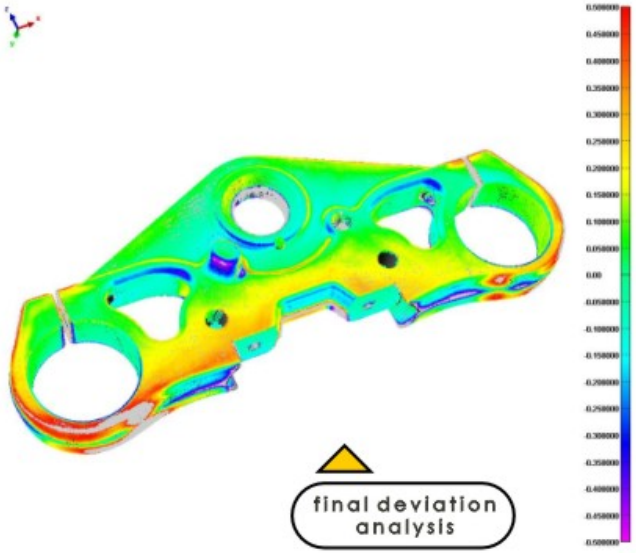
laser scanning each part

captured 3d point cloud

aligning 3d scan data



original parts



final deviation analysis

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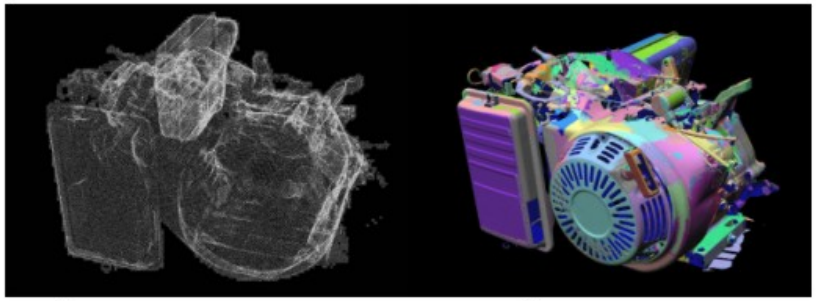
gasoline

ENGINE

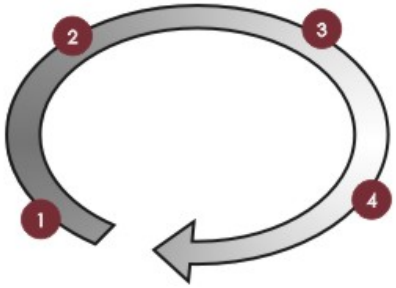
The extents and mounting points of this OEM gas engine needed to be determined so it could be installed into a new product. DDI used a laser scanner to gather a dense point cloud. The points were interpolated and output in the form of an STL file.

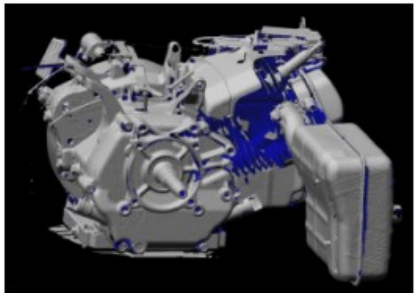


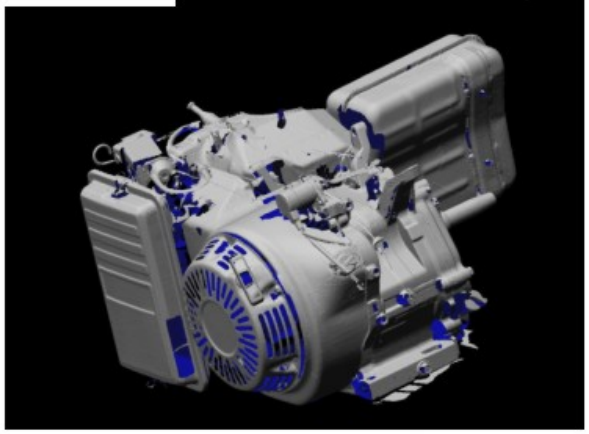
raw point cloud

patching and aligning the points

preparing and laser scanning







final CAD model

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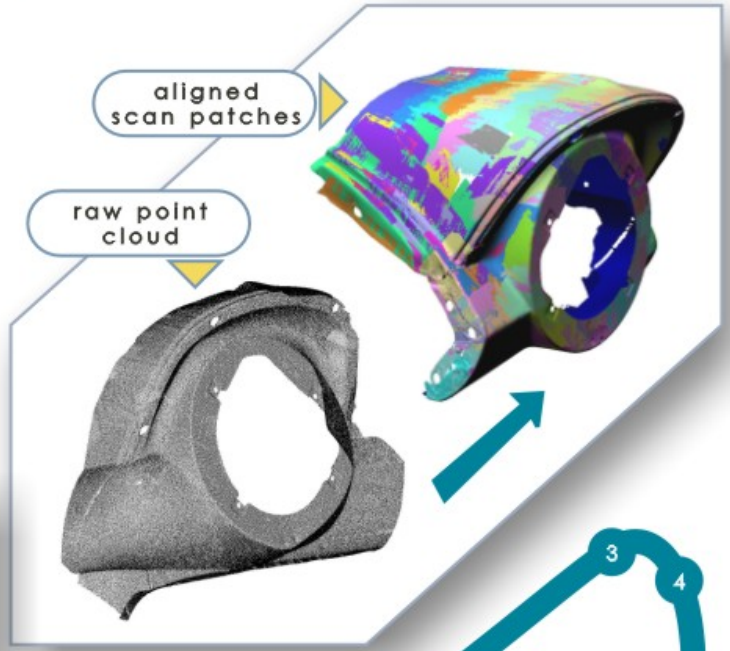
vintage

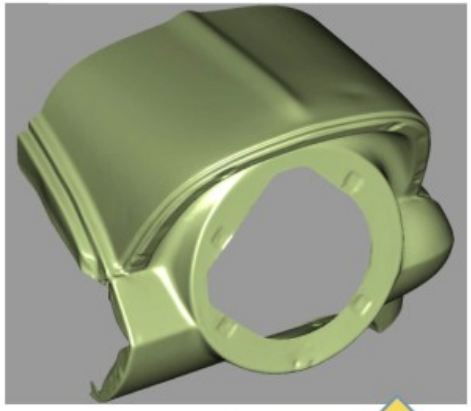
CAR FENDER

The restoration of classic automobiles has always been plagued with problems associated with formed sheet metal parts. Corrosion, dents, and scratches are sometimes so severe that the original part cannot be repaired. Laser scanning allows damaged parts to be modeled in the computer. Dents, scratches and corrosion can then be removed in the virtual model yielding a shape true to the original designer's intent. This final model can then be used to fabricate new dies and parts.

laser scanning in process



1 2 3 4 5



final surface model

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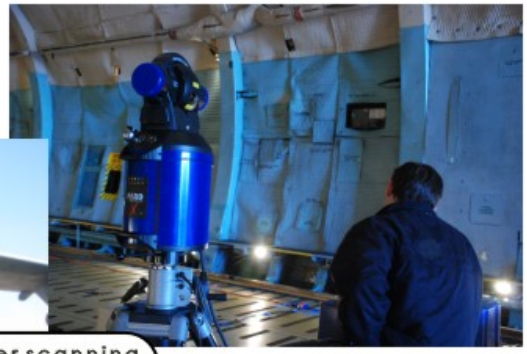
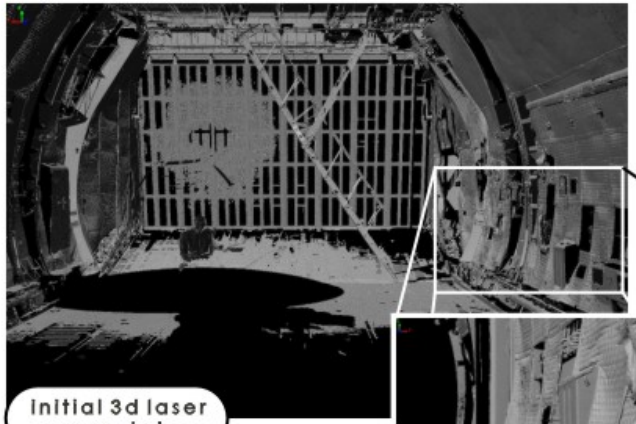
c5 aircraft

CARGO BAY

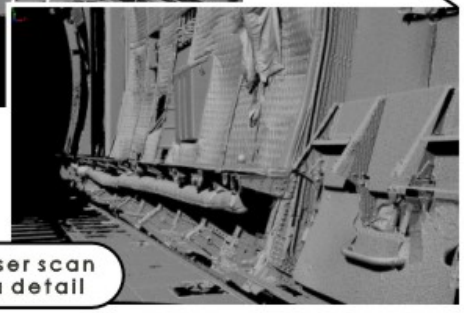
Using the Surphaser spherical scanner, DDI was able to capture over 190,000 points per second, creating highly accurate, high-resolution 3D point clouds of a C-5 cargo bay. The data was needed for space planning when filling the aircraft with equipment and other necessary items.



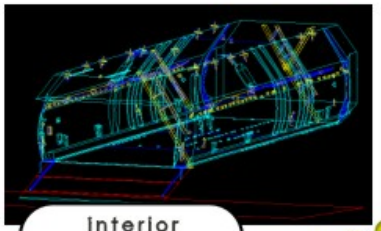
laser scanning cargo bay



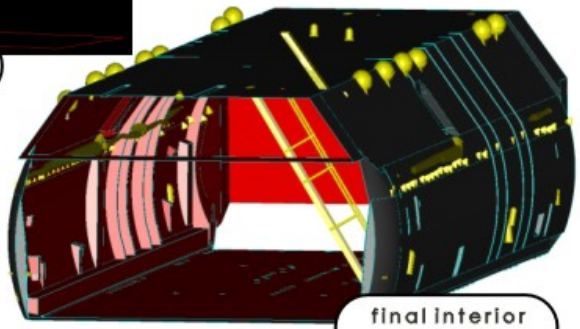
initial 3d laser scan data



3d laser scan data detail



interior surfaces



final interior surfaces

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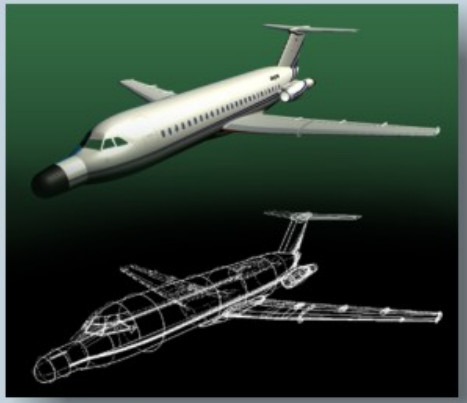
BAC-III plane

DDI measured the exterior of an entire commercial airplane using a laser tracker. The tracker was positioned in eight different positions to scan all areas. A complete accurate 3D CAD model of the entire surface was created from the raw data. The model was used for CFD analysis for modifications.



wireframe and materials

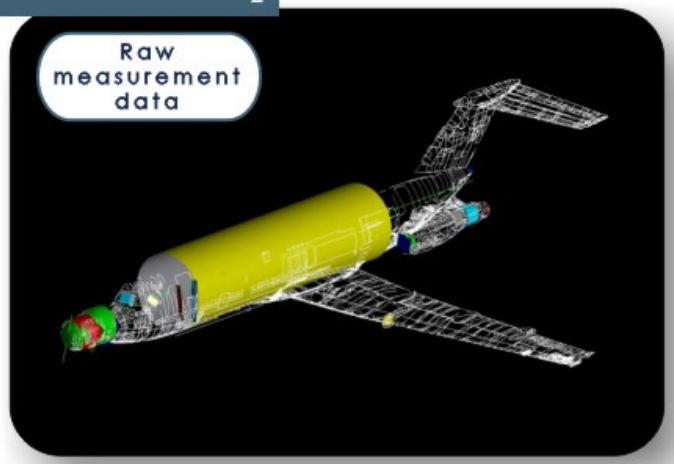
surfaced model

4 3

original airplane

1 2

Raw measurement data



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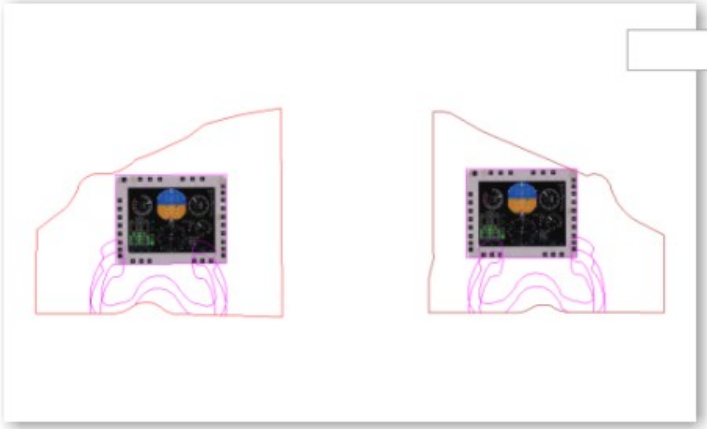
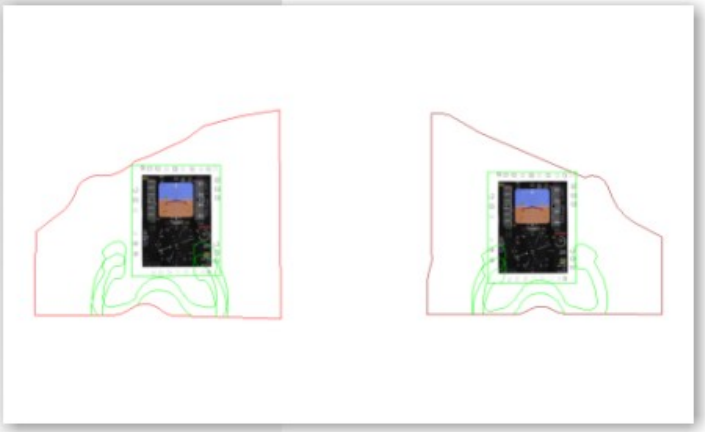
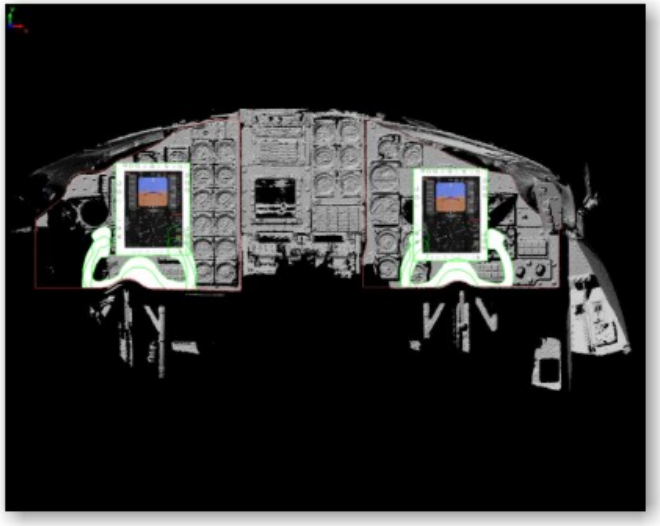
c-2 cockpit

BOTH PILOTS







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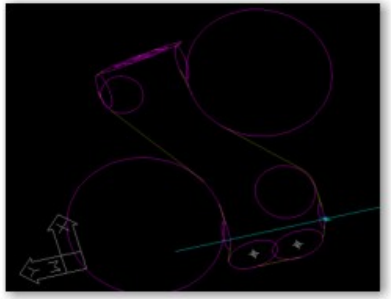
aerostructure

PARTS

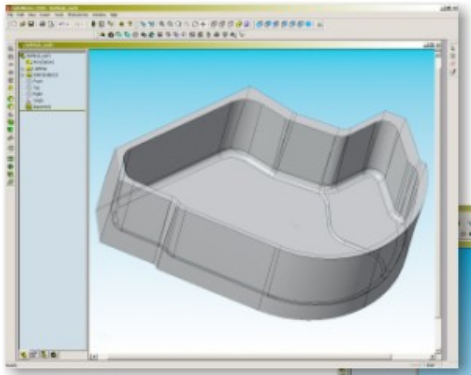
Careful measurements and precise features were captured by the point probe on the FARO arm. This data, once gathered, was output in various formats to show that the individual pieces could be reverse engineered. That data could then be used to precisely recreate each part.

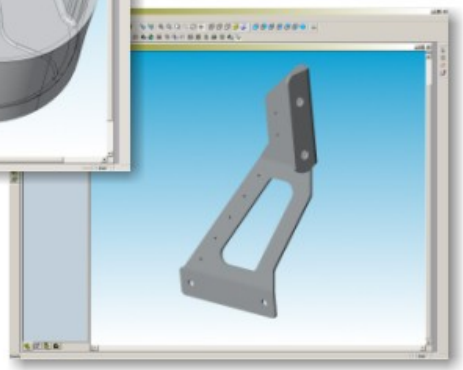
digitizing process



measured 3d cad data

original parts





final 3d cad models

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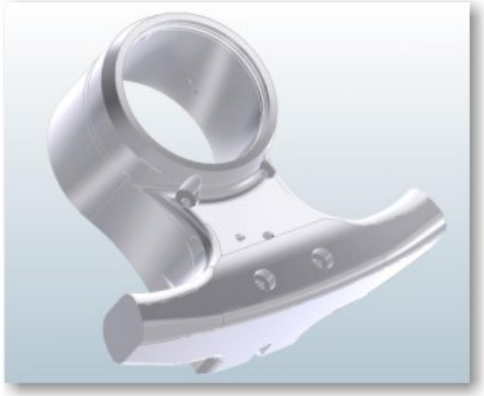
airplane
YOKE

Problem:
Client modifying a 30 yr. old yoke design had no blueprints or CAD models. The organic shape presents measurement challenges using traditional methods.

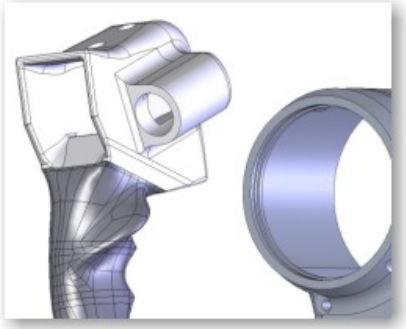
Solution:
Using Laser Scanning and Touch Probe measurement, DDI collected dimensional and surface data and recreated the "hybrid model" yoke combining geometric features with a "dumb solid" of the organic shape.

in process body + arm

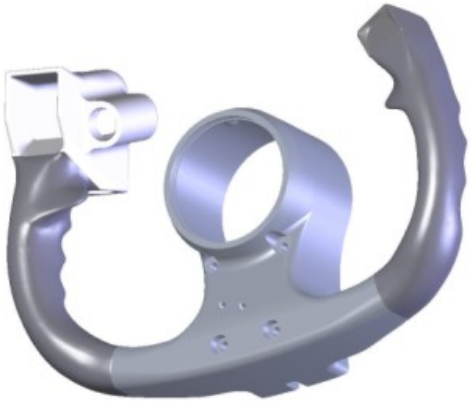


parametric surfaces

original yoke



final hybrid model



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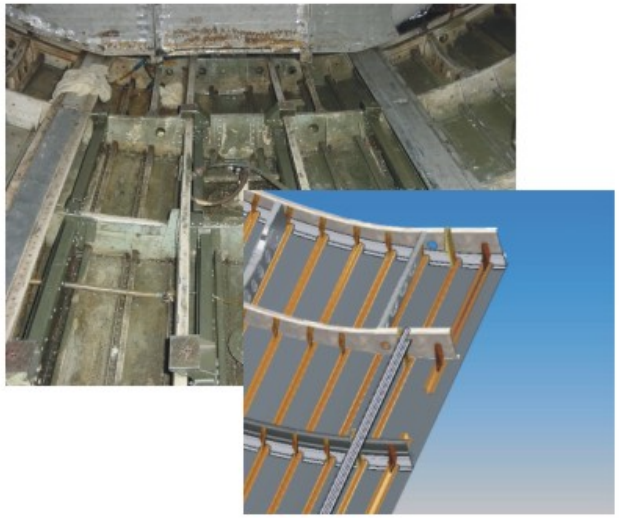
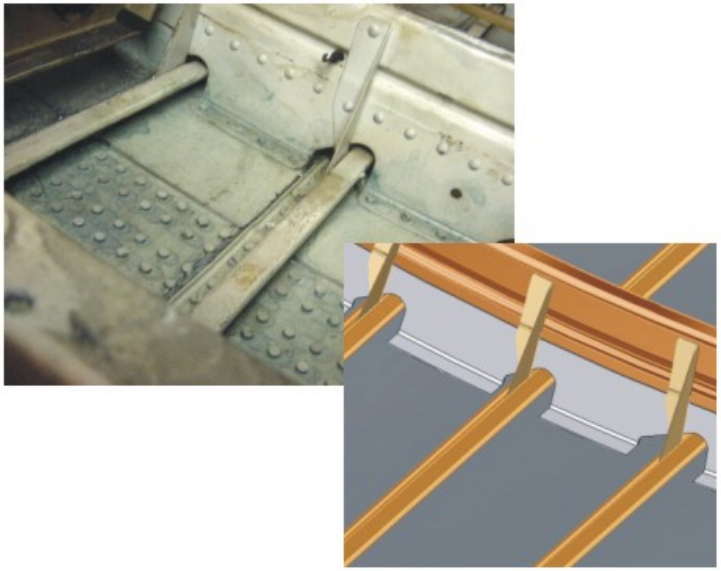
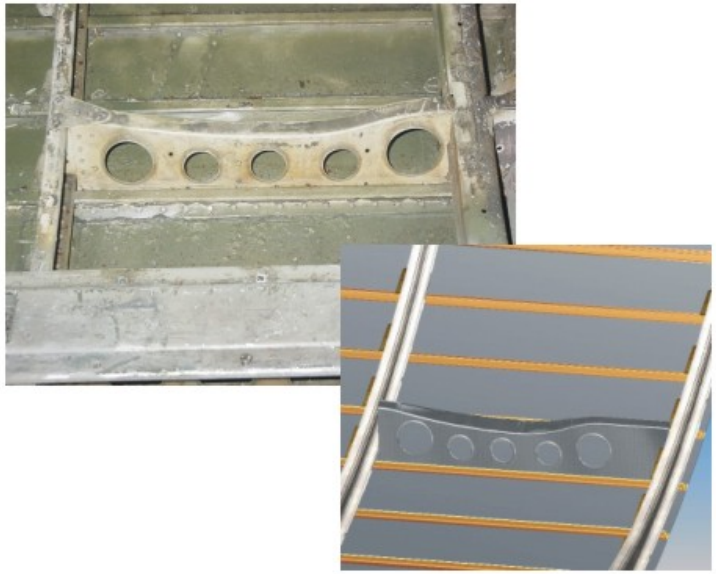
aging aircraft

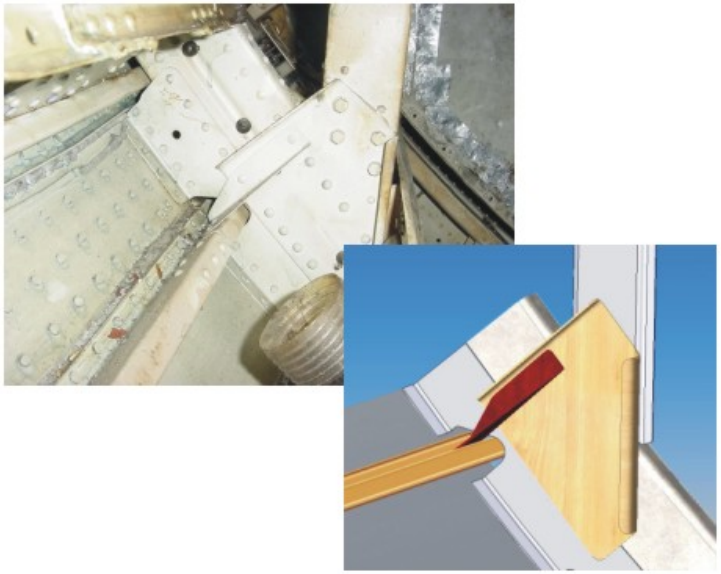
REVERSE ENGINEERING

The following examples show views of an actual aircraft internal structure versus the matching reverse engineered 3D CAD models. Using captured laser scan data, Direct Dimensions was able to precisely reverse engineer these parts into CAD data.









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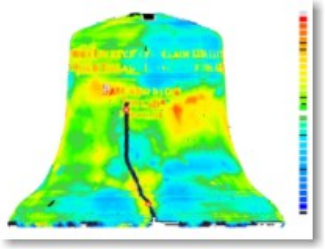
creating the

NORMANDY LIBERTY BELL

Using accurate 3D laser image data from the actual Liberty Bell, Direct Dimensions engineers created a 3D CAD model of the Pass & Stow original design from 1753 for the Liberty Bell, prior to the formation of the crack and with no casting or aging defects. This dimensional information was provided to the Cornille-Havard bell foundry in France to cast the Normandy Liberty Bell.

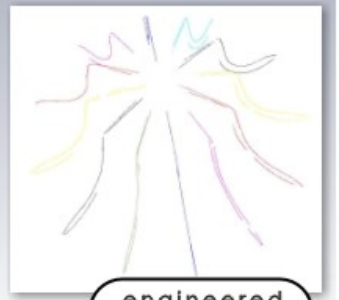
fabricating the bell

3D scan data



color deviation analysis

final revolved bell surface



engineered cross sections

final normandy liberty bell

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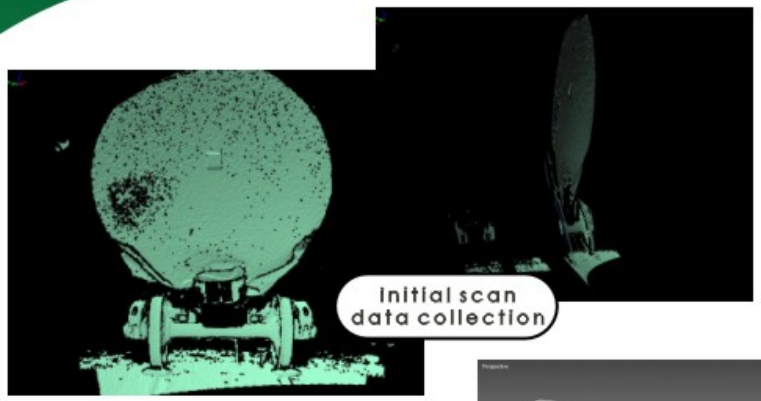
train car

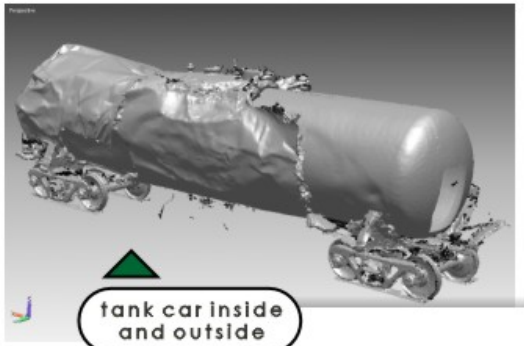
WRECKAGE

DDI was asked to laser scan the remains of tank cars that had exploded due to the pressurized chemicals inside. This data was needed to document the wreckage, as well as provide forensics experts with a starting point for their investigation.



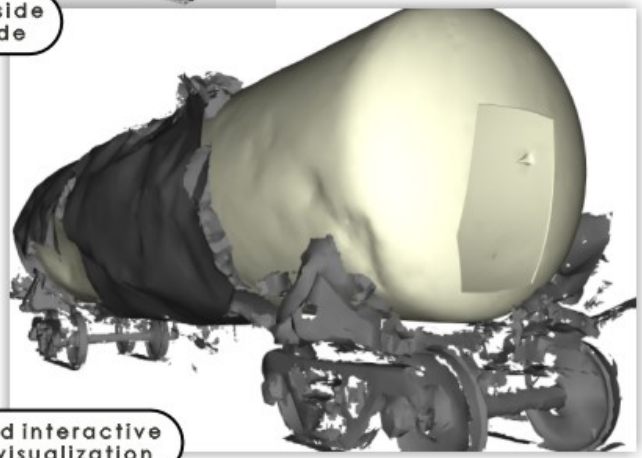
initial scan data collection

early polygonal model



tank car inside and outside

scanning train wreckage



3d interactive visualization

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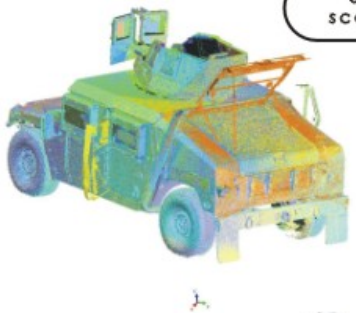
humvee armored

VEHICLE

Direct Dimensions laser scanned and modeled an armored Humvee in order to deliver a solid 3D model that would provide the client with accurate bolt locations. These bolt locations and specific parts of the vehicle were needed in 3D in order to properly retrofit additional armor and plating onto the existing vehicle.

laser scanning with the surphaser

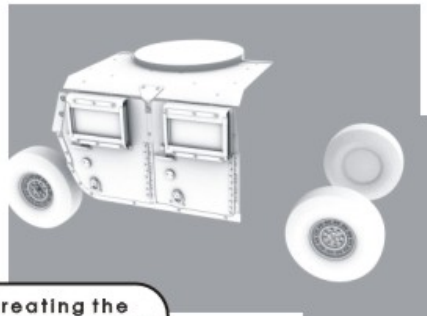


3D color scan passes

captured 3D polygonal data

original humvee prepped to scan

detail of requested area



creating the humvee surfaces

final delivered 3D solid model

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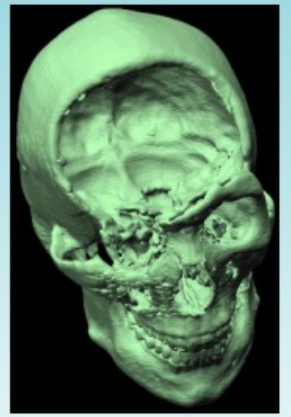
skull
IMPLANT

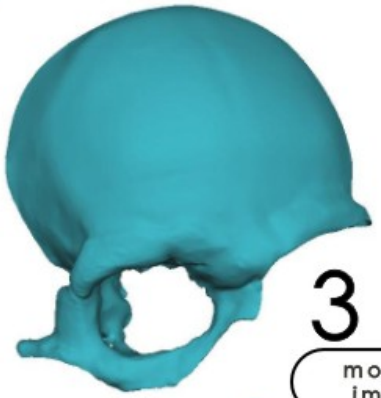
Problem:
A complete prosthetic "implant" was needed in order to reconstruct patient's skull.

Solution:
Using CT data from a full skull, DDI was able to create a piece that fit perfectly with the damaged skull. The 3D data can now be rapid prototyped and attached surgically.

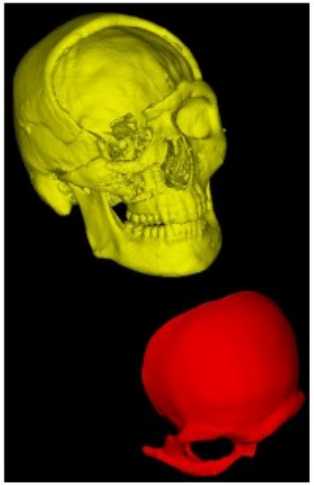


1 original skull

2 ct data of full skull

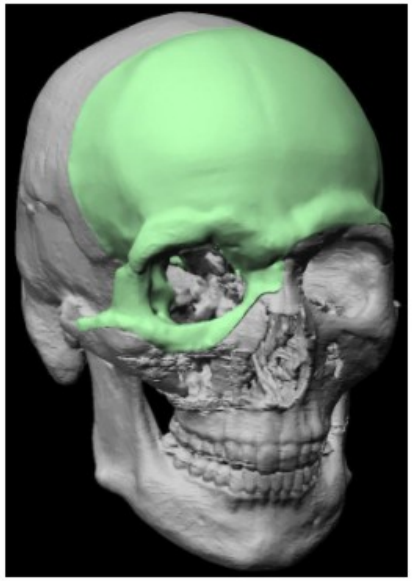


3 modified implant



4 pieces during alignment

5 precision alignment



6 final skull with implant

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Methods, Tools, and Applications for Industrial Reverse Engineering of Legacy Parts

Michael Raphael

President & Chief Engineer

Direct Dimensions, Inc.

Baltimore, Maryland

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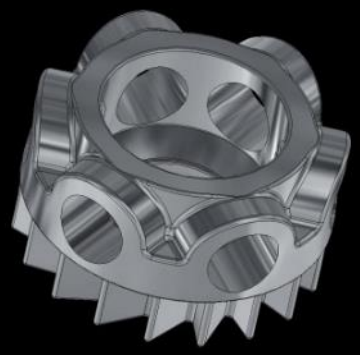
mraphael@dirdim.com



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