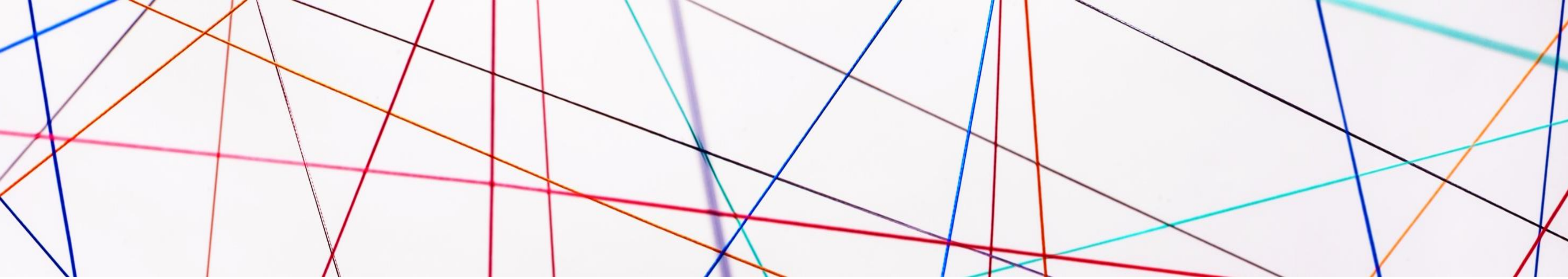


AIRBUS

# AI Driven Anomaly Detection, Localization and Quantification of Dents on Aircraft Surface

February 2025

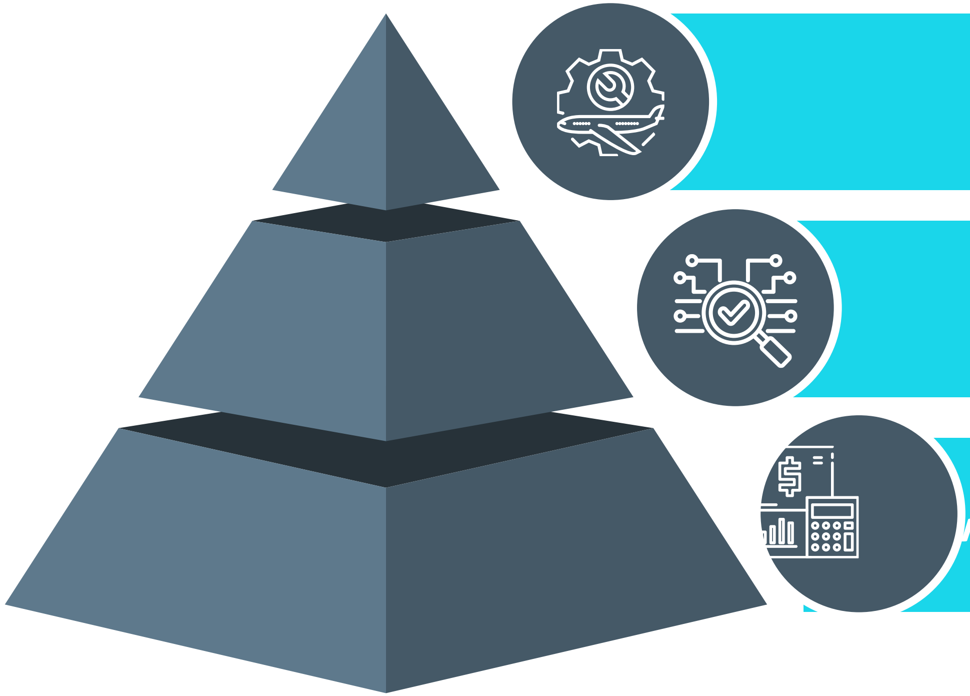
AionOS

# Contents



# Introducing AIonOS

AIonOS is at the forefront of AI innovation and dedicated to revolutionizing how businesses operate and thrive in the digital age. With a commitment to excellence and a passion for driving meaningful change, we specialize in delivering cutting-edge AI solutions that empower organizations to reinvent and optimize their business processes.



AI Native and deep tech research led

Born from deep domain expertise

ving business outcomes through products, platforms and services

**AI Native, Domain Led, Agile & Flexible, Outcome Driven**

# Our founders | Visionaries with an established tenure of 50+ years

## Rahul Bhatia

**Group Managing Director, InterGlobe**

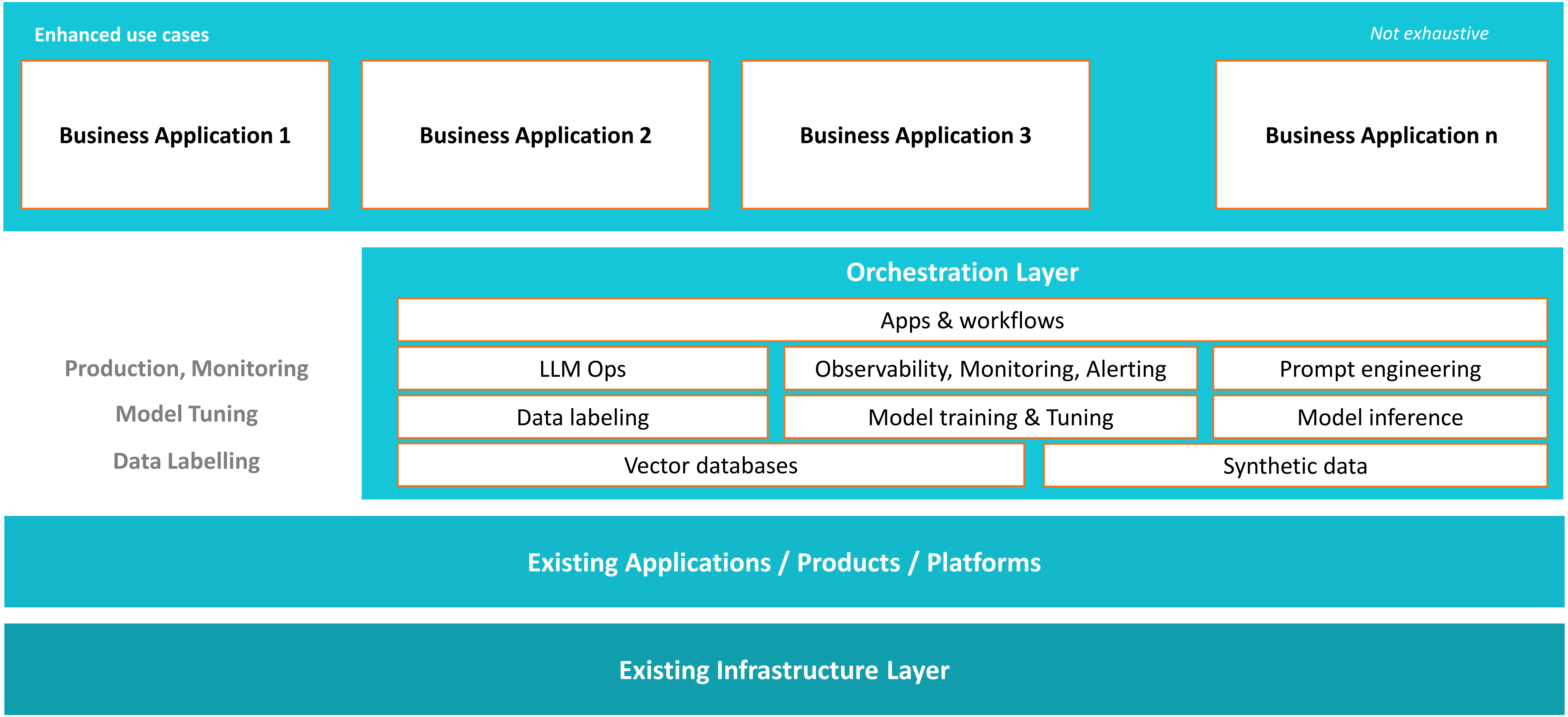
Promoter and Managing Director, InterGlobe Aviation Limited (IndiGo), India's largest and fastest growing airline

## CP Gurnani

**Prominent Global IT figure, Ex-CEO MD Tech Mahindra**

50+ years of experience in leading and growing IT business globally
Led the turnaround of Satyam to make Tech M a $7 Bn organization

# Our Goal is to build Intelligent Enterprises powered by IntelliOS



# AIonOS Capabilities

### AI-led Products and Platforms

- Whilter Video Personalisation
- Offer and Order management
- Travel and Lifestyle platform
- Cargo- Dynamic Pricing and Revenue management

### Data Intelligence Solutions

- Data Advisory
- Data Accelerators
- Data Migration factory
- Data capabilities

### Custom IT solutions

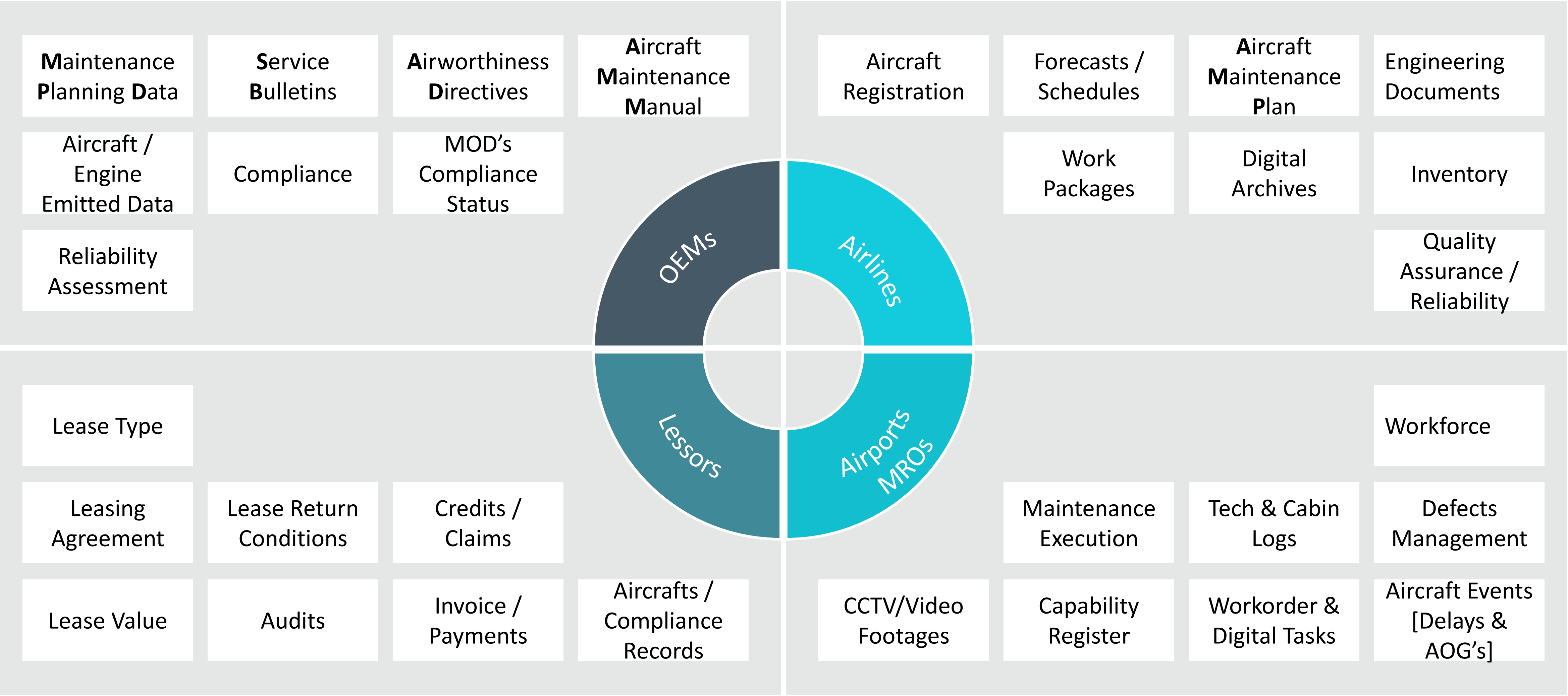
- Saas/ Paas Implementation and Integration services
- Mobile application development
- Legacy offload
- Smart- Infra management

### AI-led customer experience

- Conversational AI- Voice, Messaging and email-automation
- Customer 360, Interaction analytics
- Domain centric co-pilots

# AICORE – Engineering Data Fabric

## Building the foundation for MRO



# AI augmented 3D Structured Light Scan for Aircraft Dent Detection and Measurement

# Unplanned Maintenance cost airlines in $20.2B in 2018

## Key Challenges in Accurate Detection of Aircraft Dents

Lengthy Manual Inspection Process

Dents with complex curves and geometries or in hard to reach areas are tough to measure accurately

Poorly documented dents compromise aircraft structural integrity

Non compliance can lead to fines or grounding

# Current Damage Assessment Process

## Inspection / Localization

- An aircraft is manually searched for dents / scratches
- To identify where the dent is – standardized reference systems, zones and the aircrafts' structural components like stringers (longitudinal members) and frames (transverse) are used

## Quantification

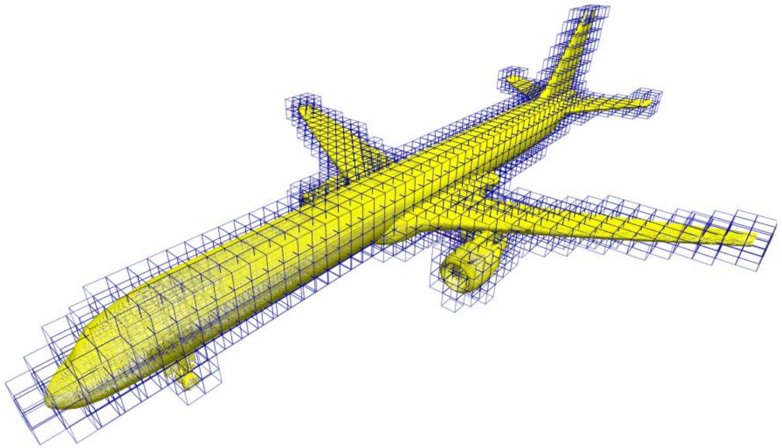
- Trace paper and markers are used to mark the size of dent

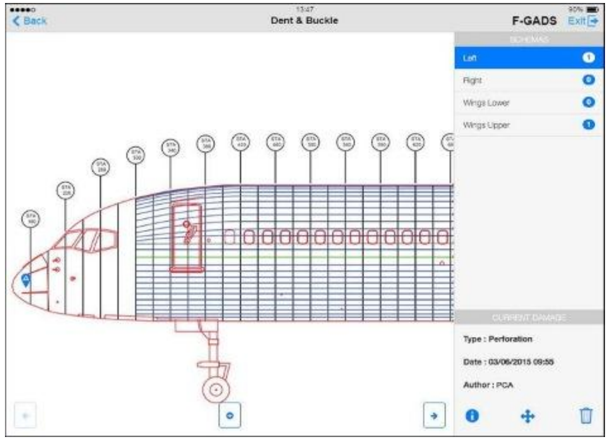
## Documentation

- Results are documented and maintenance ticket is created

## Assessment

- An assessment of extent of damage (e.g. Class II Damage) helps determine next steps



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# Sensor Based Methods

## Laser Scanning

A laser beam is projected onto the surface; sensors capture the reflection and create a 3D map. Dent depth is measured based on distortion in the laser beam. AI models analyze the 3D data for detecting dents, offering high precision and consistency.

**Accuracy:** Very High
**Cost:** High

## 3D Structured Light

- A known pattern is projected onto the aircraft surface, and cameras capture how it deforms. This creates a 3D point cloud representing the surface geometry, allowing dent detection.
- AI can analyze the 3D model for accurate dent measurements.

**Accuracy:** High
**Cost:** Medium

## Piezoelectric Sensors

- Sensors generate a voltage when pressed into the dent. This indirect measure of depth is determined by analyzing the force needed to deform the dented area.
- AI interprets sensor data, compensating for material variations and improving depth estimation accuracy.

**Accuracy:** High
**Cost:** High

## Ultrasonic Testing

High-frequency sound waves are sent into the surface; reflections from dents are analyzed to calculate the depth. AI interprets ultrasonic data to identify patterns in waveforms that indicate dent depths.

**Accuracy:** Very High
**Cost:** Very High

# Considerations and Challenges for Aircraft Dent Detection

**Distance from Camera to Dent:**

- Resolution Limitation: Decreased pixel coverage reduces detail and precision.
- Perspective Distortion: Increases with distance, misrepresenting the dent's shape and size.
- Depth of Field: Limited depth of field may cause blurring, complicating measurement.
- Light and Shadows: Distance impacts lighting, leading to shadows and incorrect estimations.

**Dents Located at Edges:**

- Geometric Distortion: Curved surfaces near edges distort dent appearance.
- Camera Angle & Field of View: Angling causes incomplete data, reducing accuracy.
- Edge Artifacts: Lens distortion at edges interferes with algorithms.
- Inconsistent Lighting: Edges alter light reflection, confusing depth estimation.
- Identifying rivets holes versus dents when present in the same scan

**Curvature Impact:**

- Managing uneven surfaces (curved, flat, irregular) and overlapping objects
- Non Uniform Depth Perception: Curved surfaces disrupt accurate depth reading.
- Distortion Due to Camera Angle: Curvature leads to foreshortening, affecting accuracy.
- Lighting & Shadow Effects: Uneven lighting and shadows complicate depth interpretation.

# PoC Focus

| | |
|---|---|
| **Problem Statement** | This project aims to digitally transform the process of detecting, localizing and quantifying features on aircraft surfaces. |
| **Objectives** | Develop an AI-driven solution that can process high quality 3D Point cloud data from aircraft surface scans to detect and classify rivets, uncategorized object and dents and classify them into Class 1, 2 or 3 based on depth. |
| **Acceptance Criteria** | **Detection Accuracy**: Detect Dents, Rivet Holes and uncategorized objects<br>**Depth Quantification** Precision: Minimum 90% precision for depth measurement with an acceptable tolerance of ±10%<br>**3D Bounding Box Accuracy**: Localization of detected objects within 3D bounding boxes with minimal error<br>**Dent Classification** : Correct classification of dents into Class 1,2,3 based on depth and specified criteria |
| **Governance** | We propose weekly meetings to ensure alignment and transparency for progress updates, challenges and model performance |

# AI Solution Approach

## Step 0 : Access Provisioning and Software Requirements

- **Access:** Collaborate with Airbus to provision access to required systems and software to access 3D point cloud data

## Step 1 : Data Processing & Preprocessing

- **Noise Removal**: Raw point cloud data captured from aircraft may contain noise due to scanning imperfections (reflections, shadows, gaps). We will explore using algorithms like **Statistical Outlier Removal or radius-based filtering** to remove outliers and ensure clean data.
- **Surface Normal Estimation**: To better understand the geometry of the surface, we'll explore using a surface normal for each point in the cloud, helping determining deviations from a smooth surface (i.e. potential dents or anomalies)
- **Segmentation**: Explore a multi-stage segmentation approach starting with unsupervised clustering (**DBSCAN**) focusing to identify broad anomaly regions. This approach will be used if the ratio of rivet holes is high.
- **Data Annotation**: The annotation will cover all the dents, objects, and rivets to obtain labeled data that will be used for training

# AI Solution Approach

## Step 2 : AI Model Development

**Dent Identification & Localization**

- We will explore **Convolutional Neural Networks**, **PointNet++** , **DGCNN** or other deep learning models adapted for 3D point cloud data. These models learn spatial features from the point cloud, allowing for accurate segmentation of dents even on complex, curved surfaces. Segmentation provides pixel-level precision in 3D, crucial for dent depth analysis.
- Each detected object will be enclosed in **3D bounding boxes** with key values (center coordinates, width, height, depth).

**Dent Depth Quantification**

We will explore using the difference between the baseline (smooth surface) and the dented area to measure depth accurately.

- We will attempt to use mathematical **surface fitting** and **distance metrics** to quantify the depth in microns.
- To predict depth directly based on point cloud- we will attempt **depth regression** models and then explore **sensitivity analysis** for outlier points and irregularities as well as real-time comparison with known rivet hole standards to improve accuracy in depth measurement.

# AI Solution Approach

## Step 2 : AI Model Development

| Classification of Dent | Based on the criteria mentioned about depth we will use advanced decision trees or rule-based AI for classification of Class 1,2 and 3 dents.<br>**Class 1 Dent**: Dents ≤100 µm deep, outside-in, with smooth contours and a ratio A/D ≥ 25.<br>**Class 2 Dent**: Dents ≤500 µm deep, applicable to dents both inside-out and outside-in, with rules such as skin thickness ≤ 4mm and undamaged areas around the dent.<br>**Class 3 Dent**: Any dent that exceeds 500 µm or does not fulfill Class 1 and 2 criteria. |
|---|---|
| Model Exploration | In cases where model efficacy is uncertain, we will explore additional AI models and techniques such as **anomaly detection**, as well as different models like **DBSCAN, Support Vector Machines (SVM), and Random Forest** to refine detection and classification. |

# AI Solution Approach

## Step 3 : Testing & Validation

| | |
|---|---|
| **Data Splitting** | We will split the dataset provided by Airbus as training and testing set for rigorous validation. |
| **Performance Metrics** | Models will be evaluated based on their ability to:<br>• Accurately classify dents as per categorization criteria<br>• Quantify depth with high precision<br>• Detect rivet holes and other features with minimal false positives.<br>• Introduce a **Confusion matrix** to measure the precision, recall and F1 score of each class of dent detection to provide more insights into the performance of model. |
| **User Acceptance Testing** | Testing to be done on additional data by  Airbus for validation and check. |

# AI Solution Approach

## Step 4 : Delivery & Deployment

The final solution will be deployed as an API capable of accepting 3D point cloud data and basic UI/UX returning:

- Detected features (Dents and rivet holes)
- Depth measurements for each dent .
- Localization of detected objects
- Classification of each dent into Class 1, 2, or 3.

# Key Milestones

| | | |
|---|---|---|
| Step 1 | Final project strategy & Architecture | 1 week |
| Step 2 | Feature identification / detection | 4 weeks |
| Step 3 | Localisation of the features | 2 week |
| Step 4 | Dent Measurements | 4 week |
| Step 5 | UI , UX | 1 week |
| Step 6 | APIs and Software Interface | 1 week |
| Step 7 | Documentation & Handover | 1 week |

**14 weeks**

# Dependencies & Assumptions

- Availability of software for managing 3D point cloud data .
- To achieve higher model accuracy, we may require additional training data with higher variation or variety of data which would include different structural features (curved surface etc.) and higher volume of data for model improvement.
- As thickness data will not be provided therefore specific ratios criteria D/T will be excluded for the classification purpose.
- Airbus Team may perform UAT on additional data from their end for model validation and accuracy check.

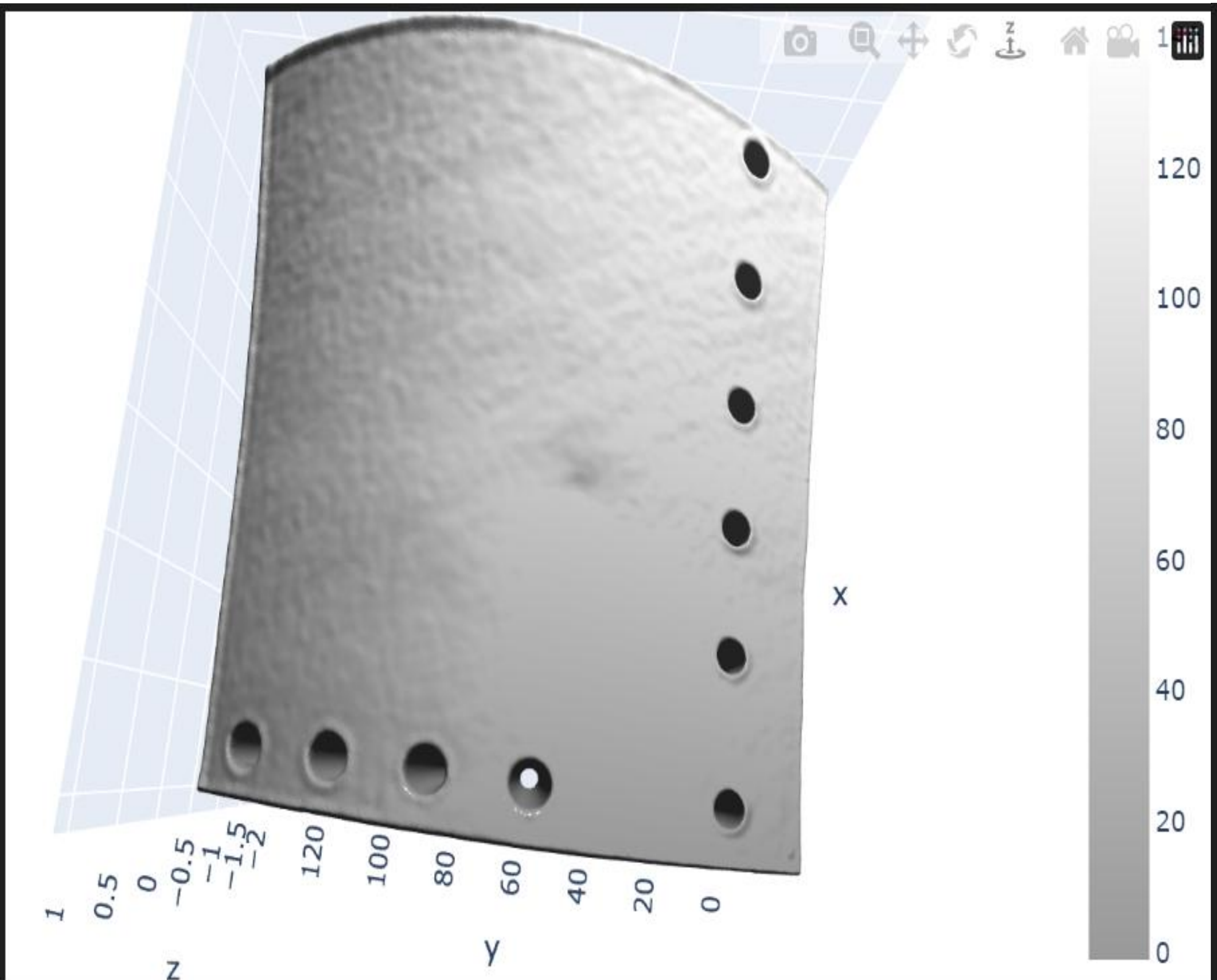
# Challenges We Are Attempting to Solve

**Managing uneven surfaces** (curved, flat, irregular) and overlapping objects: A possible approach is using multi-object detection techniques like **YOLOv4** which can detect objects in crowed spaces or **feature fusion** techniques to combine features from multiple layers of the model to enhance detection

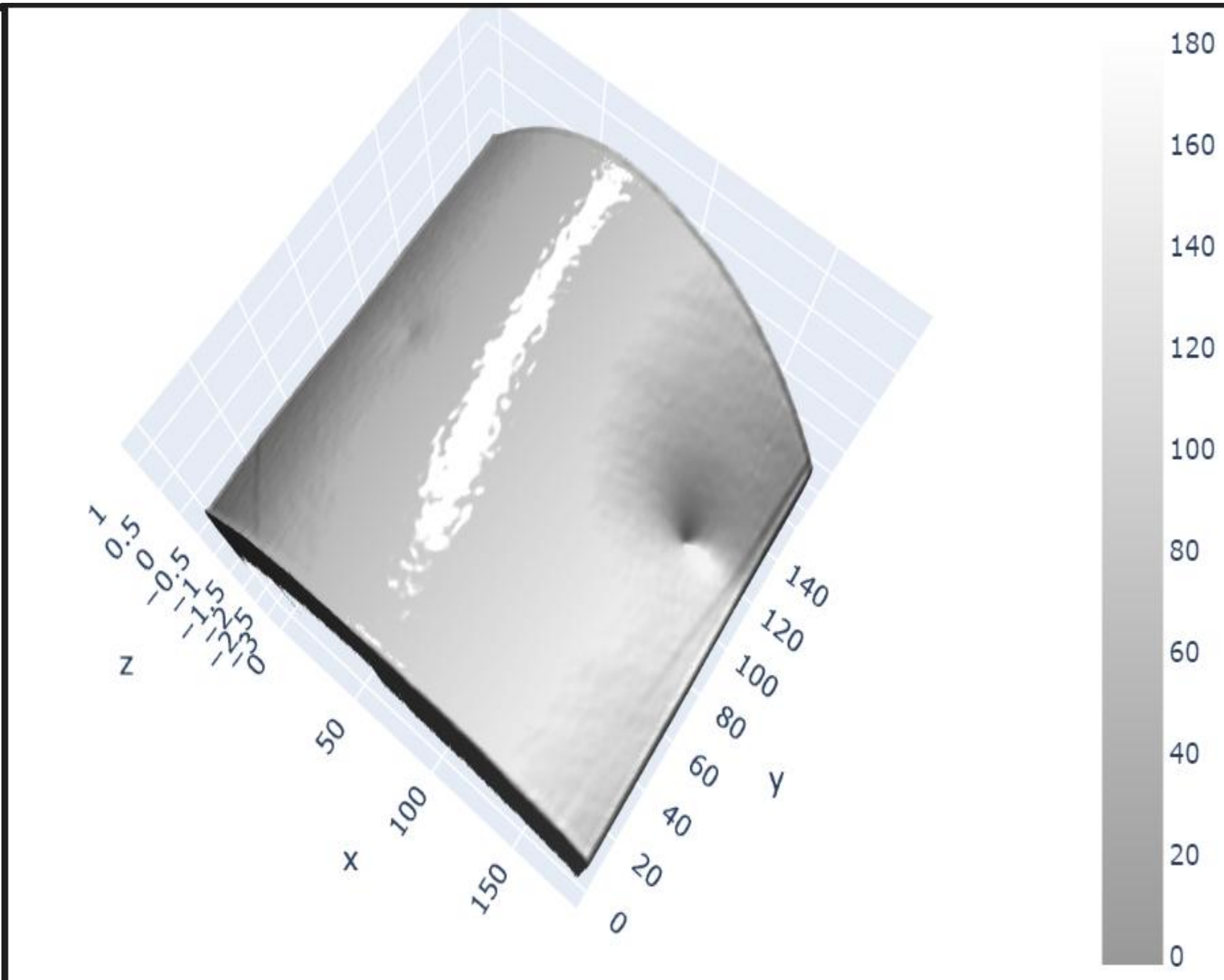
**Identifying rivets versus dents when present in the same scan**: Can explore an advanced, multi-stage segmentation (apply broader segmentation initially to classify anomalies and non-anomalies to isolate regions of interest and then more refined segmentation like supervised learning and leveraging manually labeled data. Furthermore, **hybrid segmentation** methods combining both classical algorithms and deep learning models can be evaluated to improve accuracy in segmenting the closely spaced objects.

# Sample 3-D Point Cloud Data of Aircraft Surface

Aircraft component surface with rivets

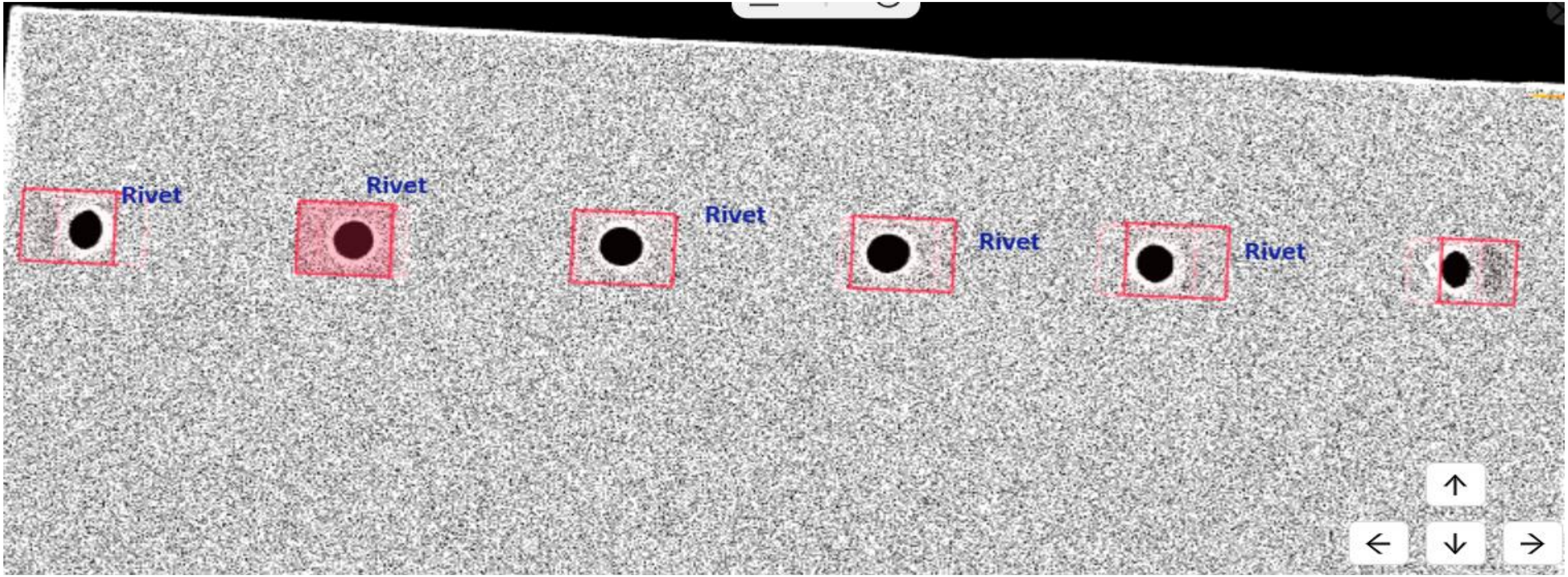



Aircraft component surface with dent



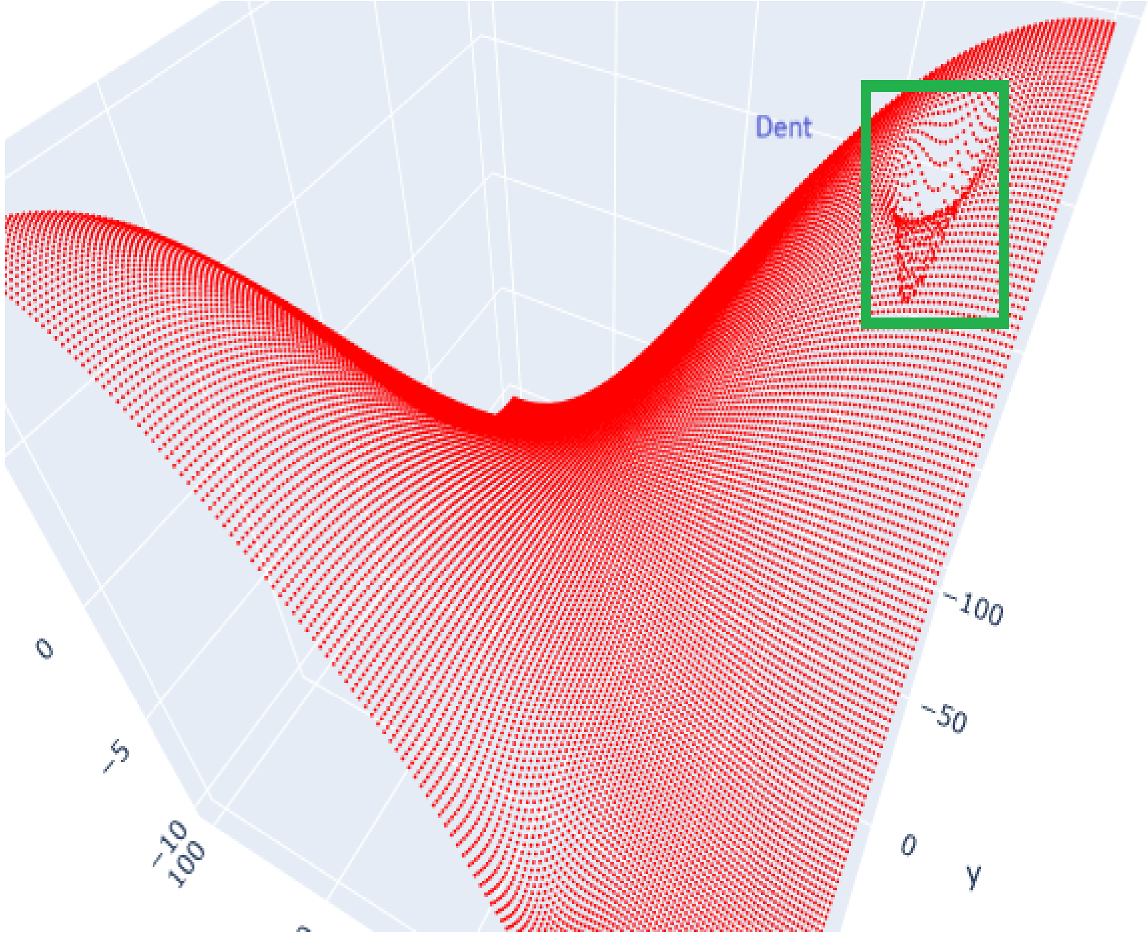
# Sample Annotated Data of Aircraft Surface

Point Cloud data with Rivets

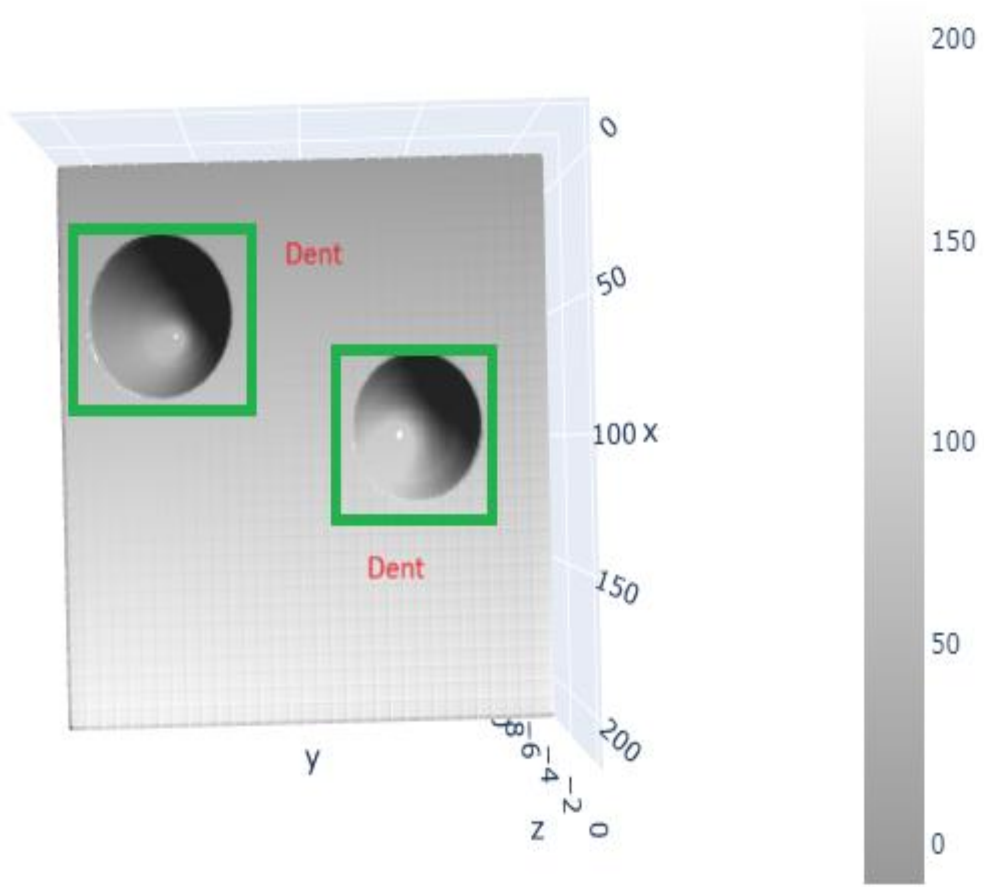


# Sample Synthetic Data & Annotation of Aircraft Surface

Point Cloud data with curved surface




Mesh data with flat surface



# Thank you!