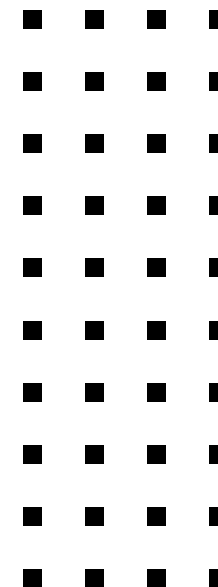


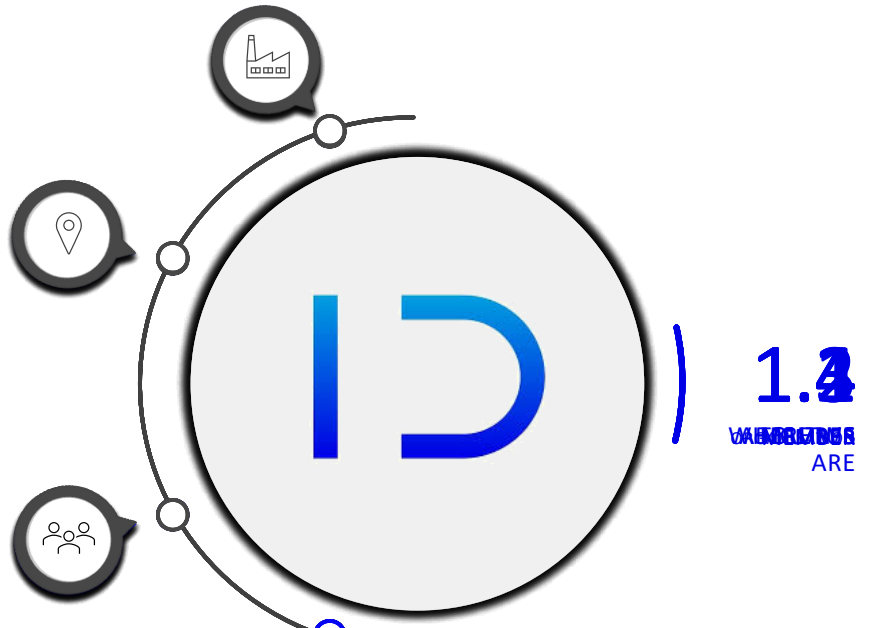
Accurate Photogrammetry Based on Molded Markers

IDEKO, Basque Research and Technology Alliance (BRTA), 20870 Elgoibar, Spain




Iñigo Auzmendi Iriarte, Oier Saez de Egilaz, Pedro Gonzalez de Alaiza, Ibai Leizea


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1.4
MEMBERS ARE









Mondragon is one of the leading Spanish business groups, with 4 production sectors around the world:

- Finances
- Industry
- Retail
- Knowledge


Total Incomes

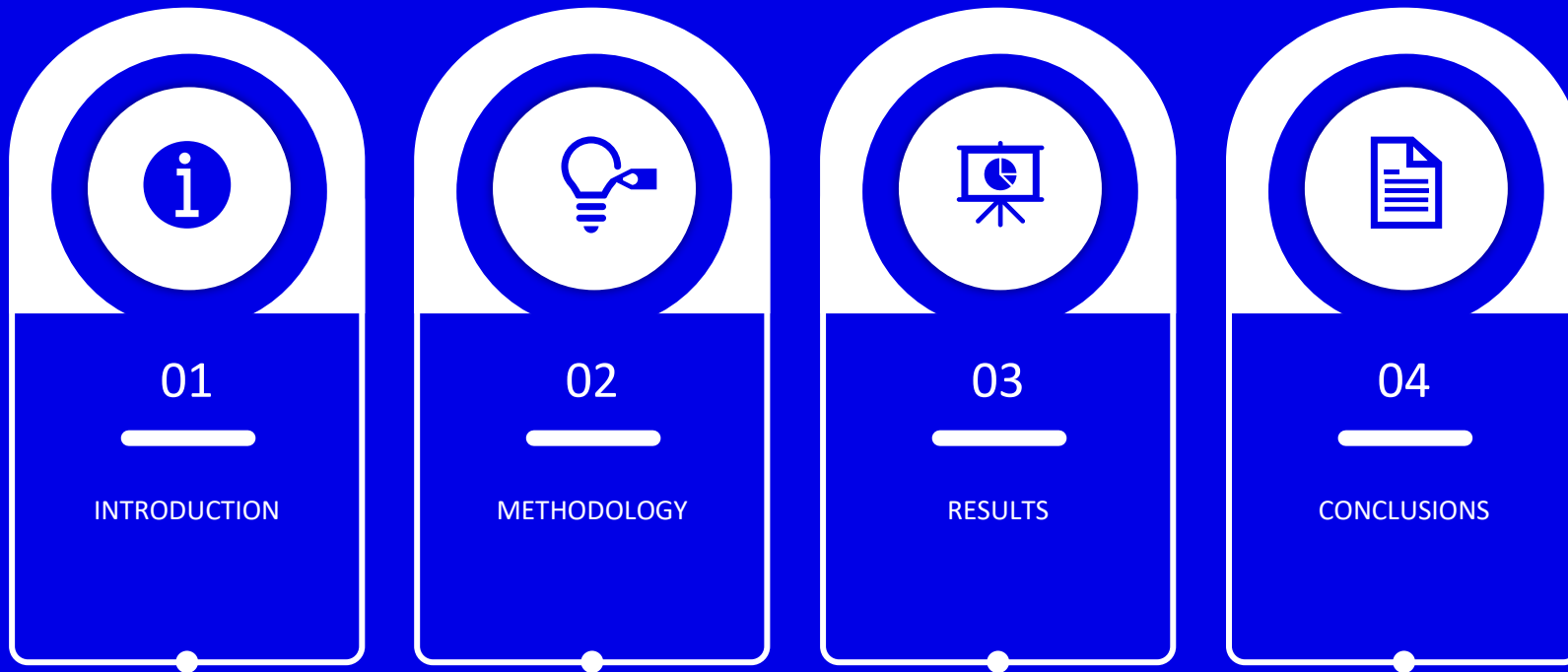
2024  11 213 million €

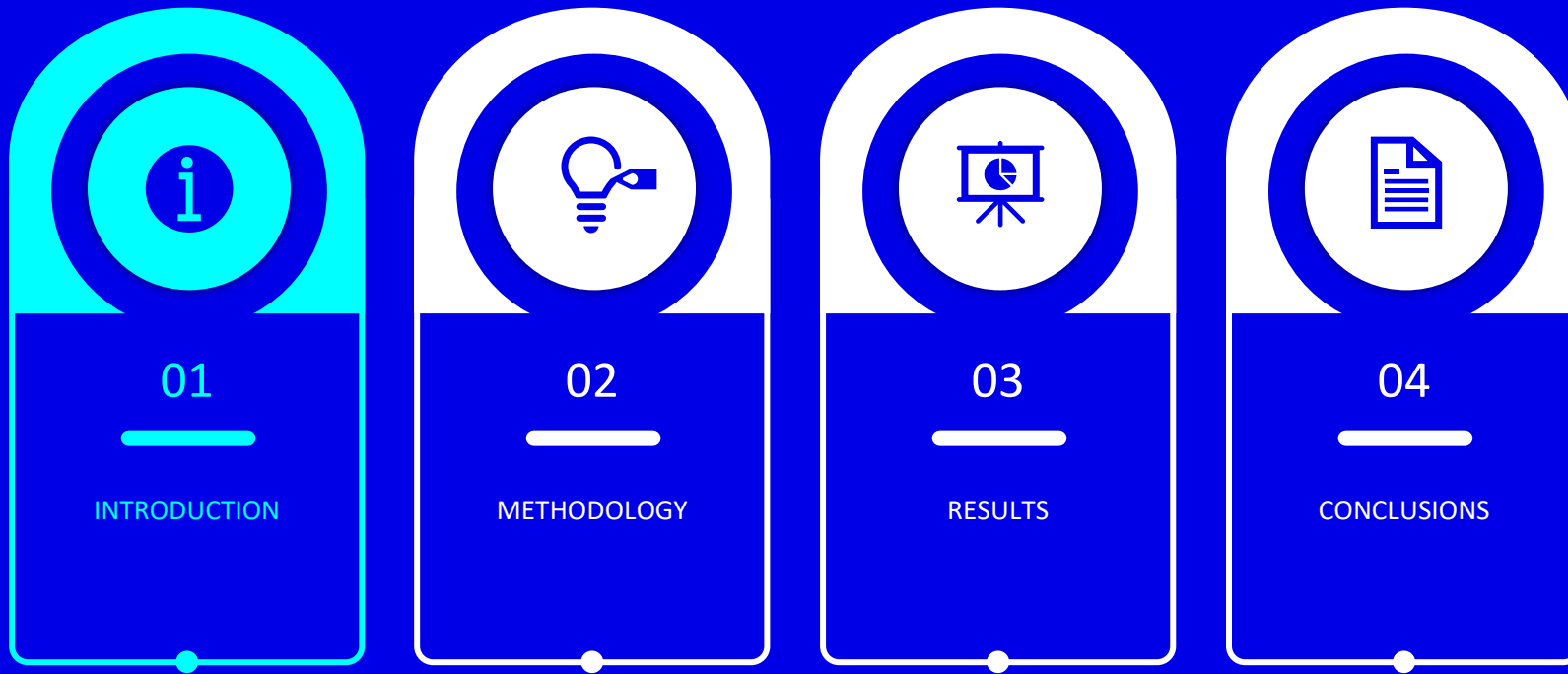
Staff

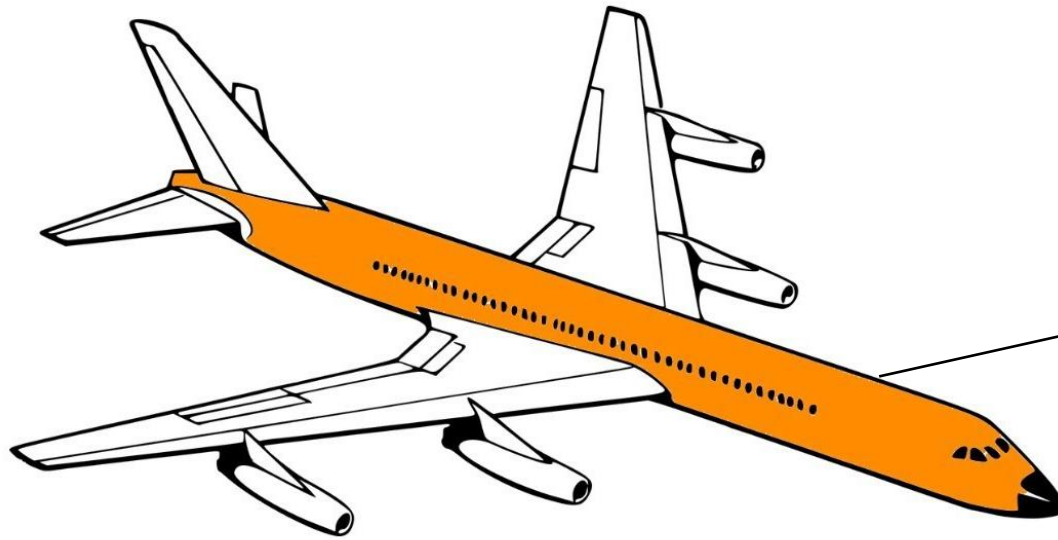
2024  70 085 people

Researches

2024  2 012 researches







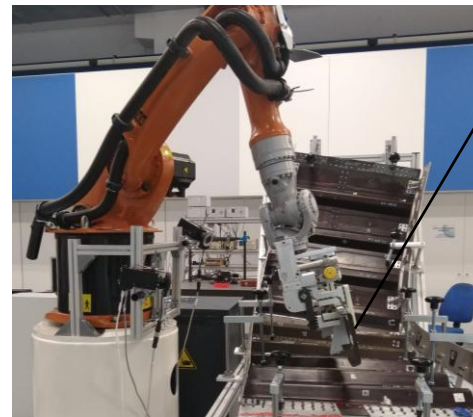
FUSELAGE

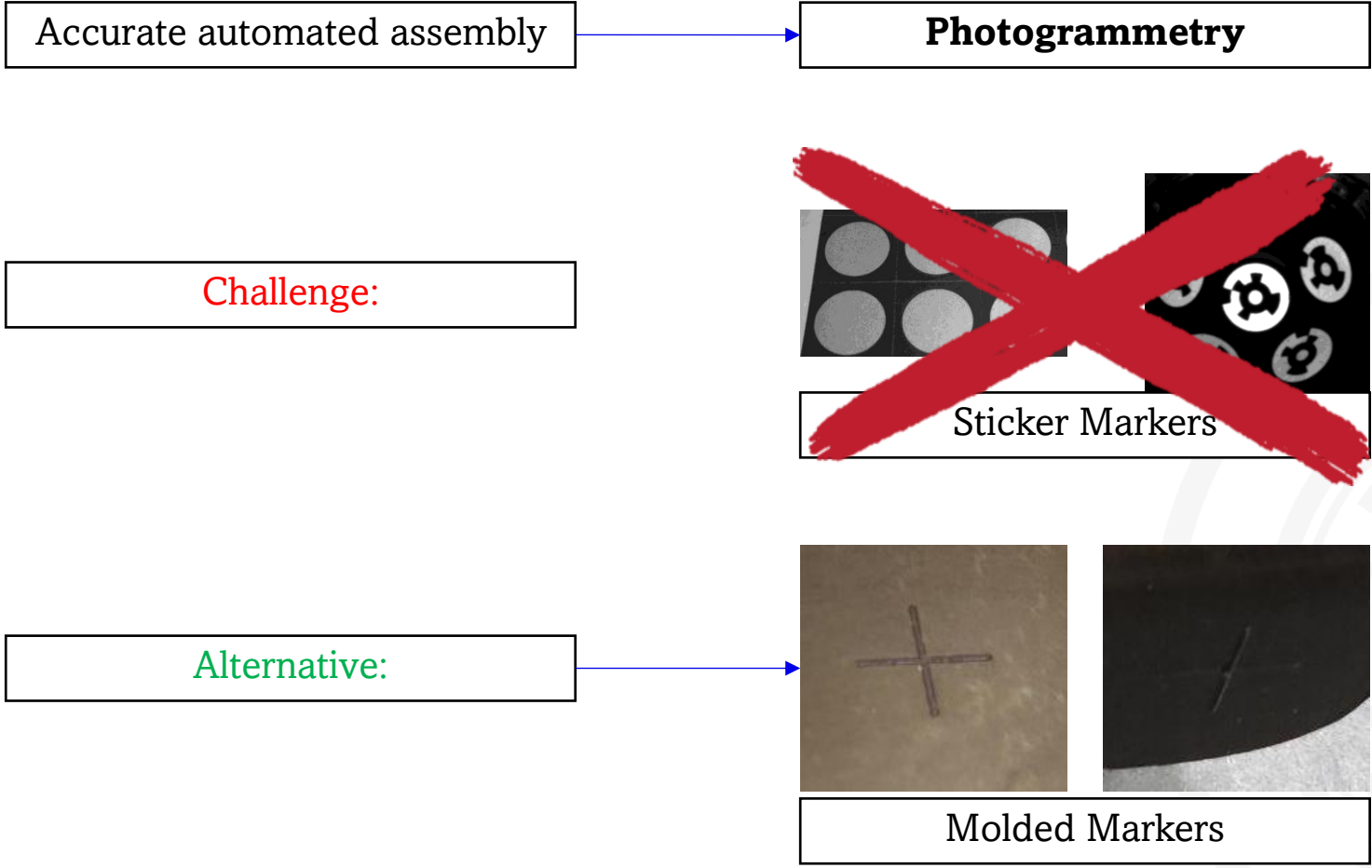


Frame: reinforcement to increase the stiffness of the fuselage

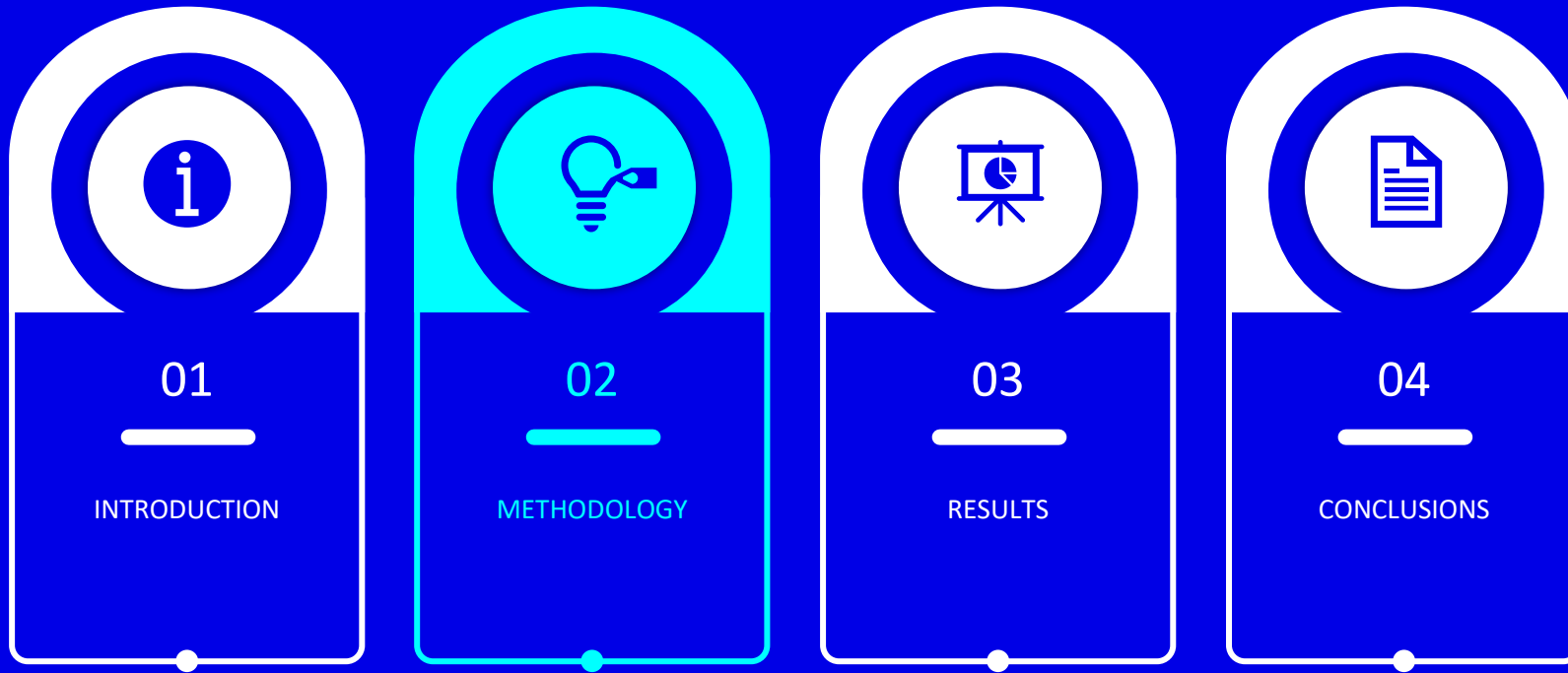
-
-
-
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-

Accurate automated assembly of frames



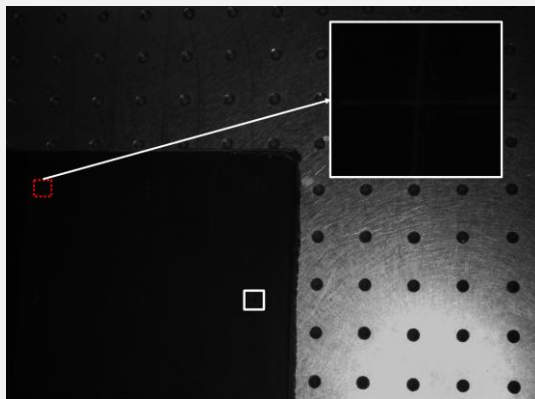


How to accurately detect the marker centre?

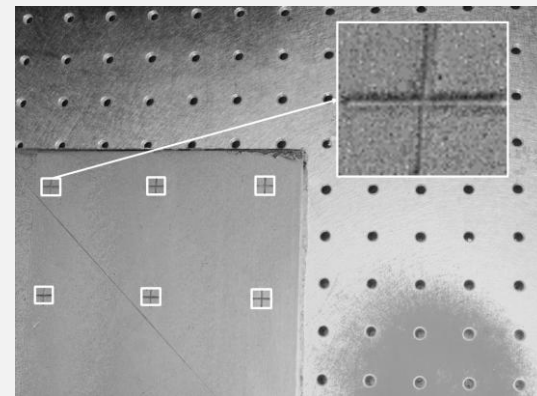


REQUIREMENTS

- CFRP Composite material
- Non-reflective markers
- Dedicated illumination
- Reliable center detection at ~500 mm standoff distance



Grayscale Image



DoP



FLIR Blackfly S BFS-PGE
Polarimetric Camera



Lens

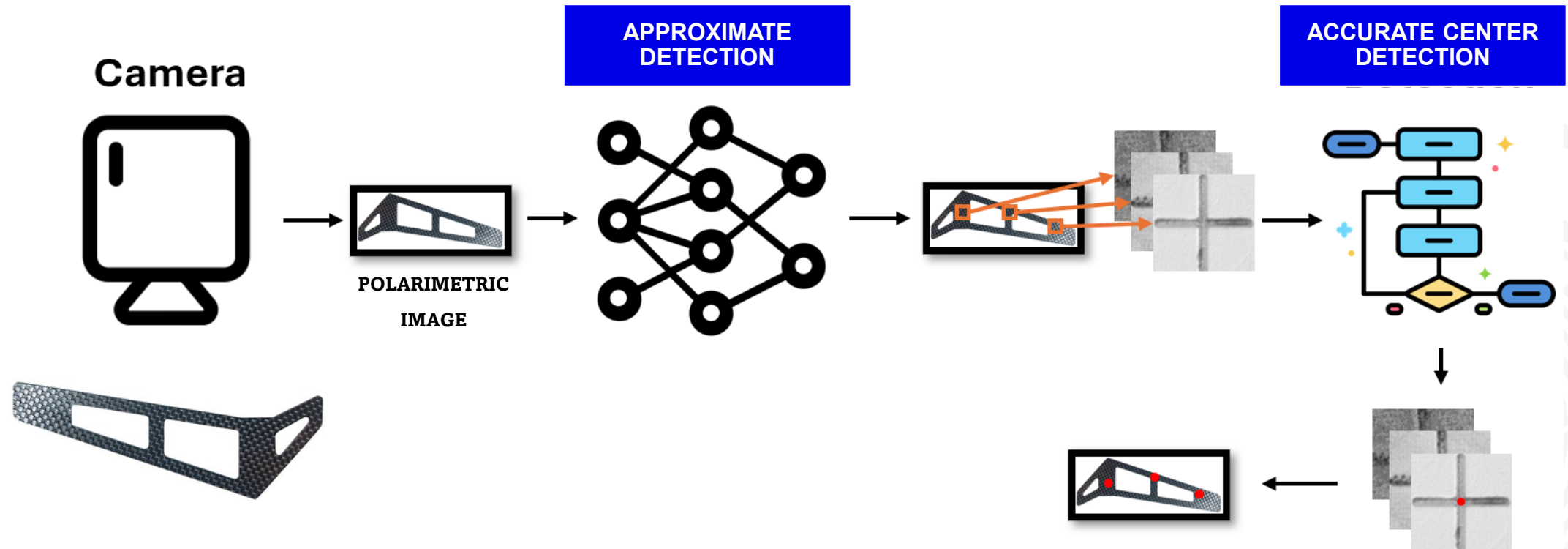


LED illumination

BENEFITS

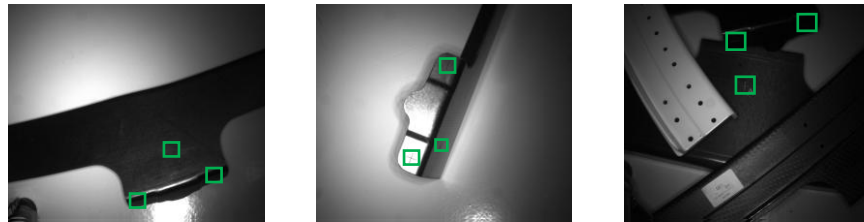
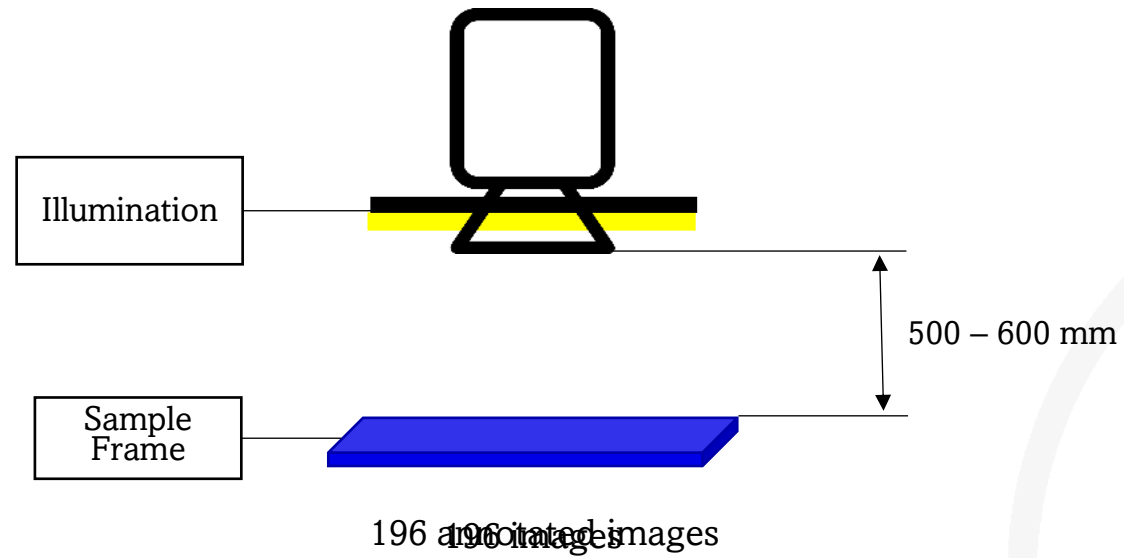
- Measures reflected light polarization, not just intensity nor colour
- AoP (angle of polarization) and DoP (degree of polarization)
- Large measurement volume

TWO STEP APPROACH



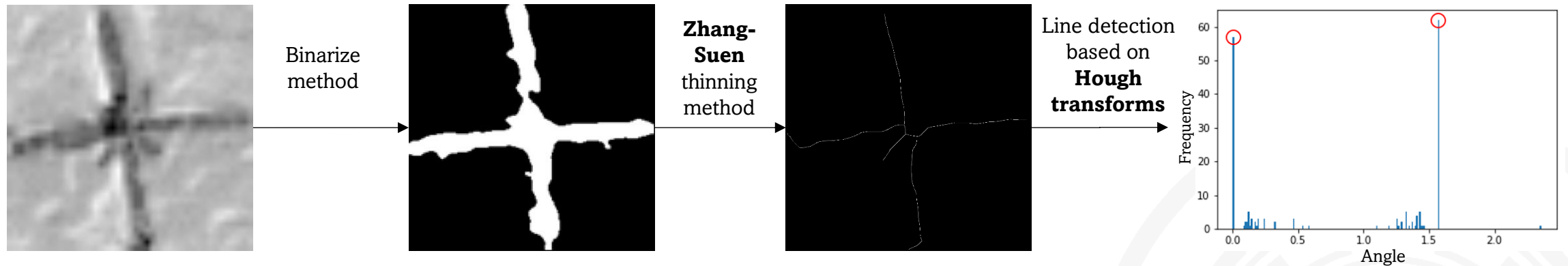
TWO STEP APPROACH

APROXIMATE DETECTION



TWO STEP APPROACH

ACCURATE CENTER DETECTION



- Intersection of the two main axes → marker centre
- No two prominent directions → discard
- If binarized image \neq ideal cross → discard

GROUND TRUTH

17 molded markers measured with Leica AT960 + AS1 scanner (± 0.03 mm)

MEASUREMENT SCENARIO

1. Polarimetric camera, lens, and illumination mounted on a robot arm.
2. Robotic arm gripper tracked using a multi-camera optical system (± 0.05 mm).
3. Robot mounted on a linear track to fully cover the aeronautical component (3600×1300 mm).
4. Robot-sensor system calibrated.



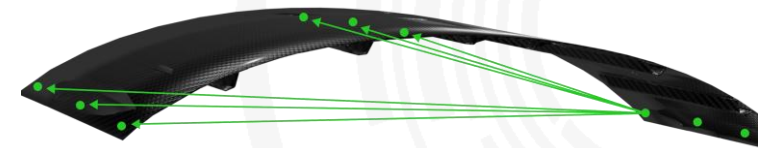
MEASUREMENT PROCEDURE (Per Marker)

1. Capture five polarimetric images from different perspectives
2. Triangulate using the detected marker centers and apply robot pose estimation from the multi-camera system to obtain global 3D points.



RESULT COMPARISON

Calculate distances between molded markers and compare them with the ground truth.





APROXIMATE DETECTION

Faster R-CNN successfully trained using data augmentation:

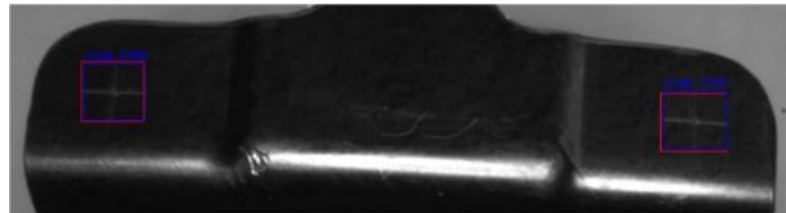
mAP50:

No data augmentation	Rot + flip
84%	96%

No significant improvement observed when adding polarization information:

mAP50:

Grayscale	10, 145, 190
94%	96%



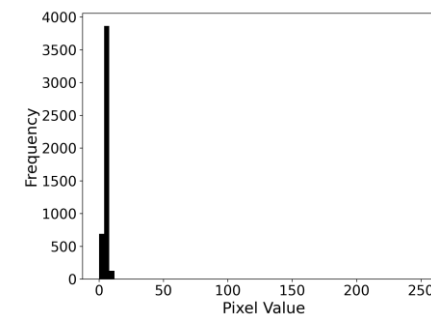
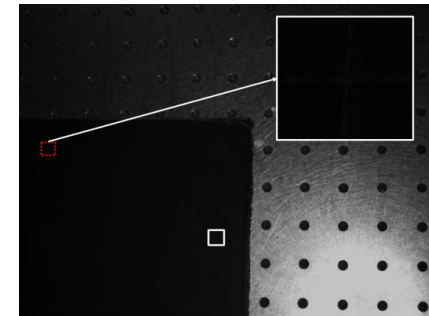
ACCURATE CENTER DETECTION

Polarization improved the detection rate of the accurate method by 79%

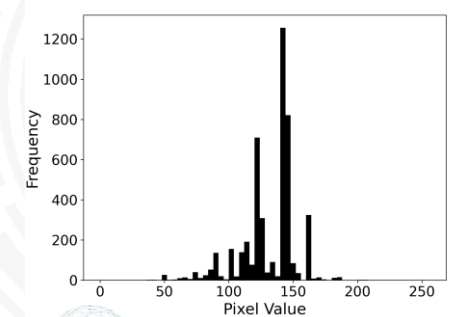
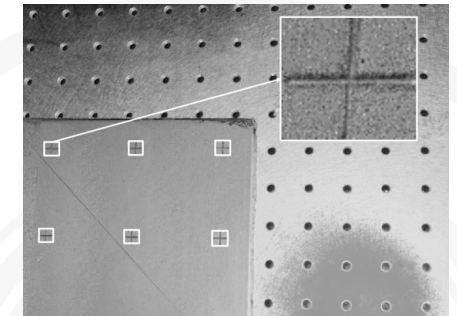
Center detection rate:

Grayscale	DoP
48%	86%

Grayscale



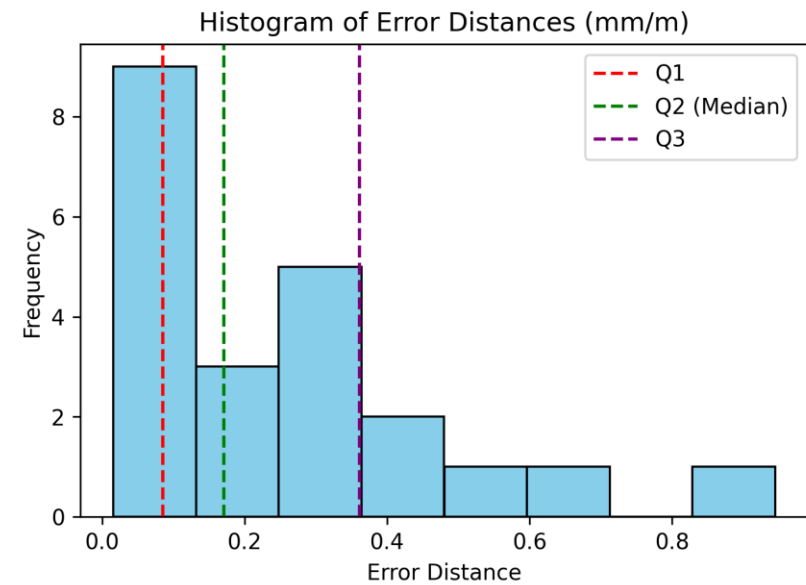
DoP

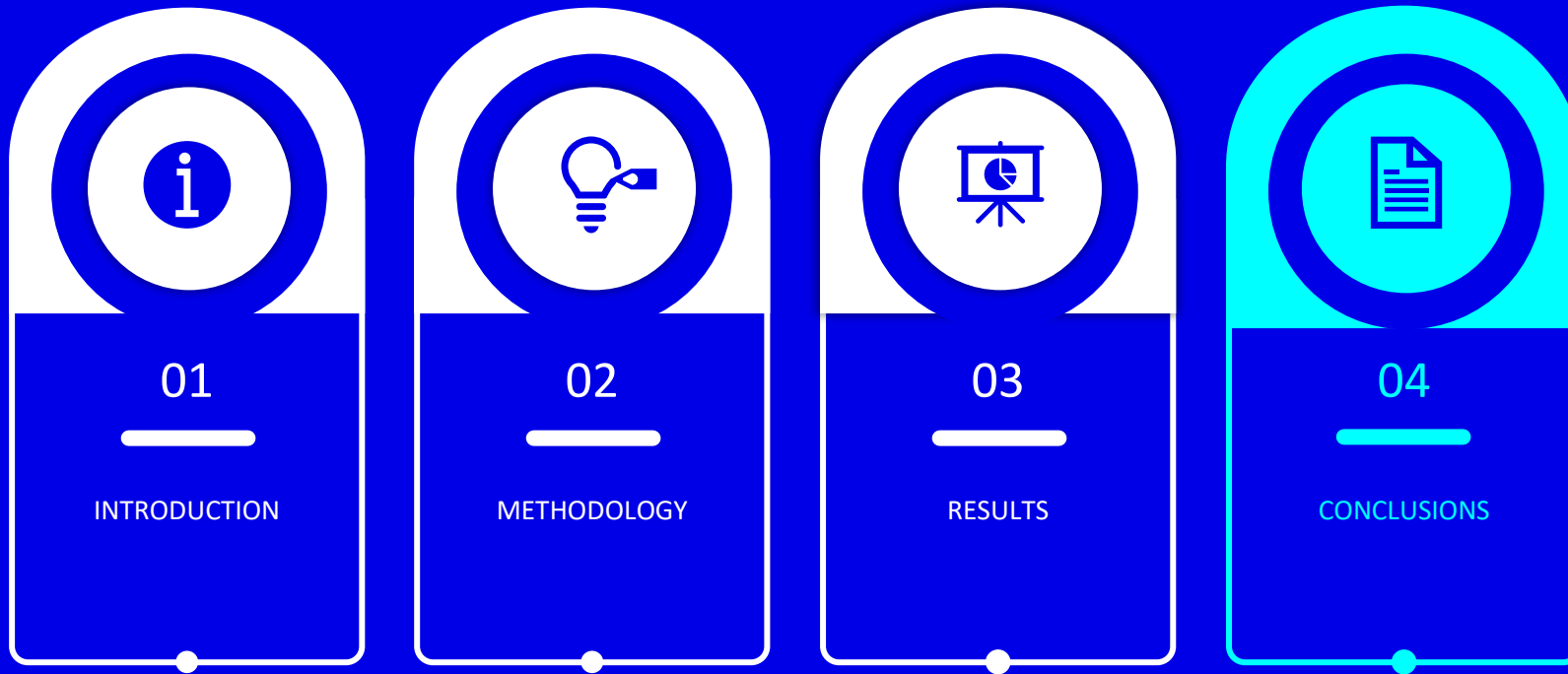


VALIDATION MEASUREMENT ERROR

Experimental results:

- Median error: 0.17 mm/m
- Interquartile range (IQR): 0.069 – 0.368 mm/m
- Expanded uncertainty (k=2): 0.463 mm/m

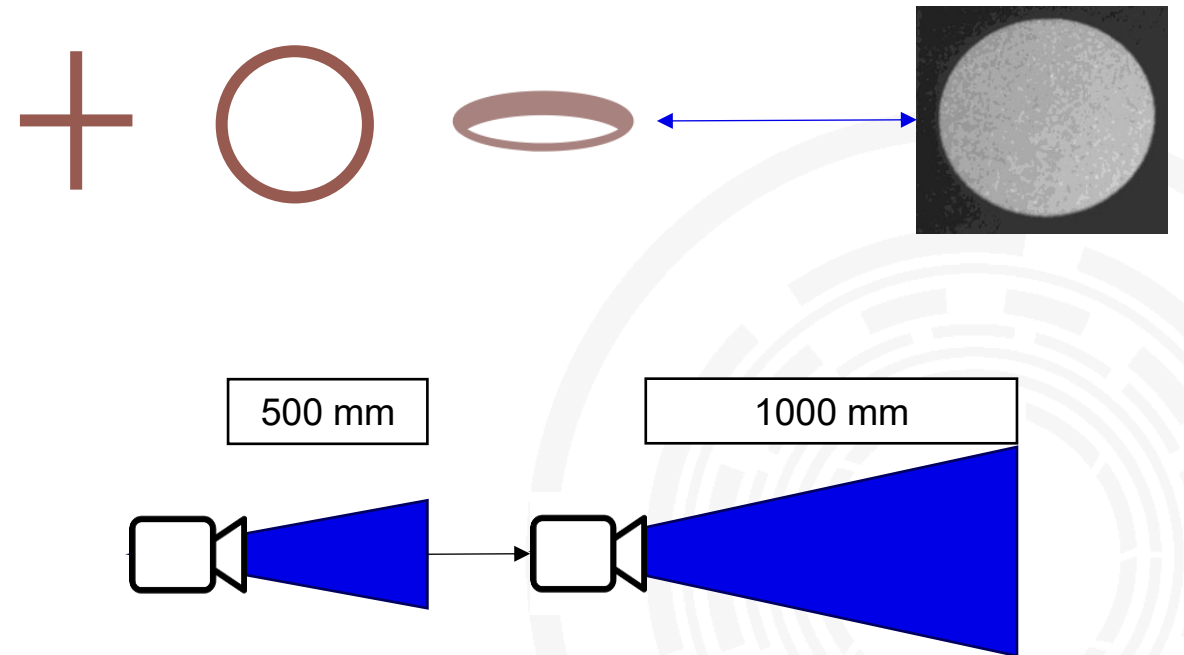


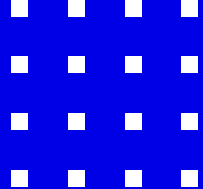


1. Introduced a new type of fiducial marker
2. Approximate detection can be performed using grayscale images (94% mAP)
3. Polarization-based imaging improves the detectability of molded marker centers by 79%
4. Demonstrated **viability** in an industrial scenario, achieving accuracy (median 0.17 mm/m) suitable for multiple applications



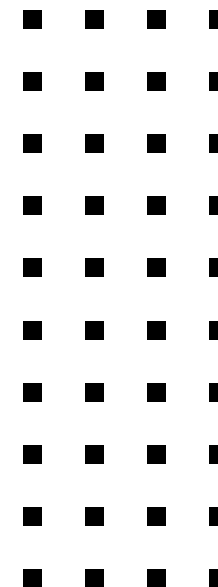
- Evaluation of molded markers with different shapes
- Extensive accuracy comparison with respect to optical markers
- Data-driven approaches for centre detection
- Extension to larger measurement volumes.





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FUNDED BY: Biostruct



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