Re-Wind
NEWS PRODUCTS PEOPLE
DRIVING INNOVATION IN THE
RE-USE OF DECOMMISSIONED WIND TURBINE BLADES

Reconstruction of Wind Turbine Blade Geometry and Internal Structure from Point Cloud Data

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Georgia Institute of Technology

Atlanta, Georgia

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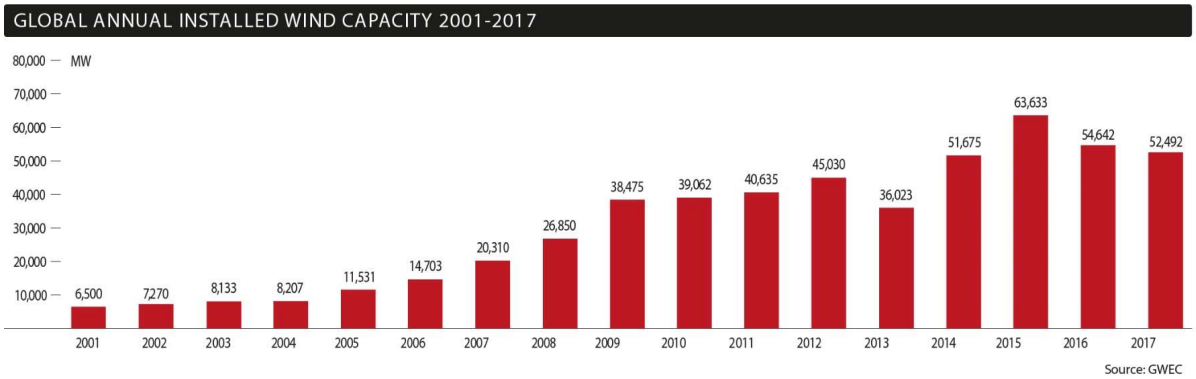
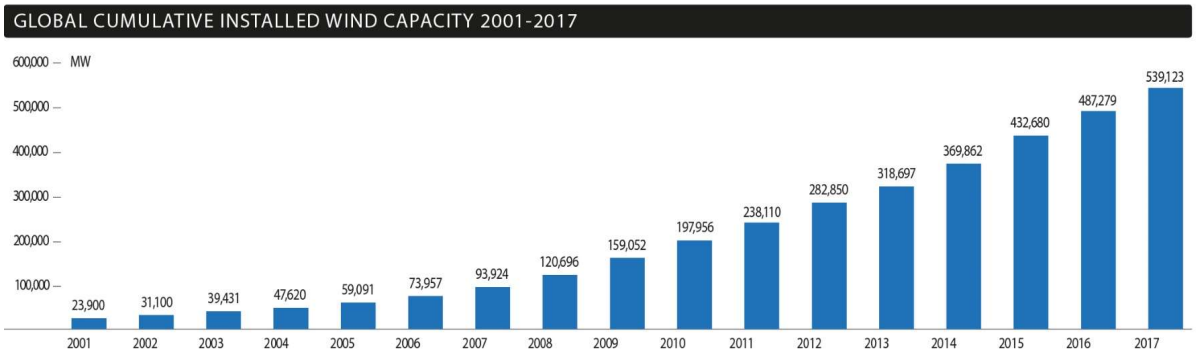
Wind Energy since 2001

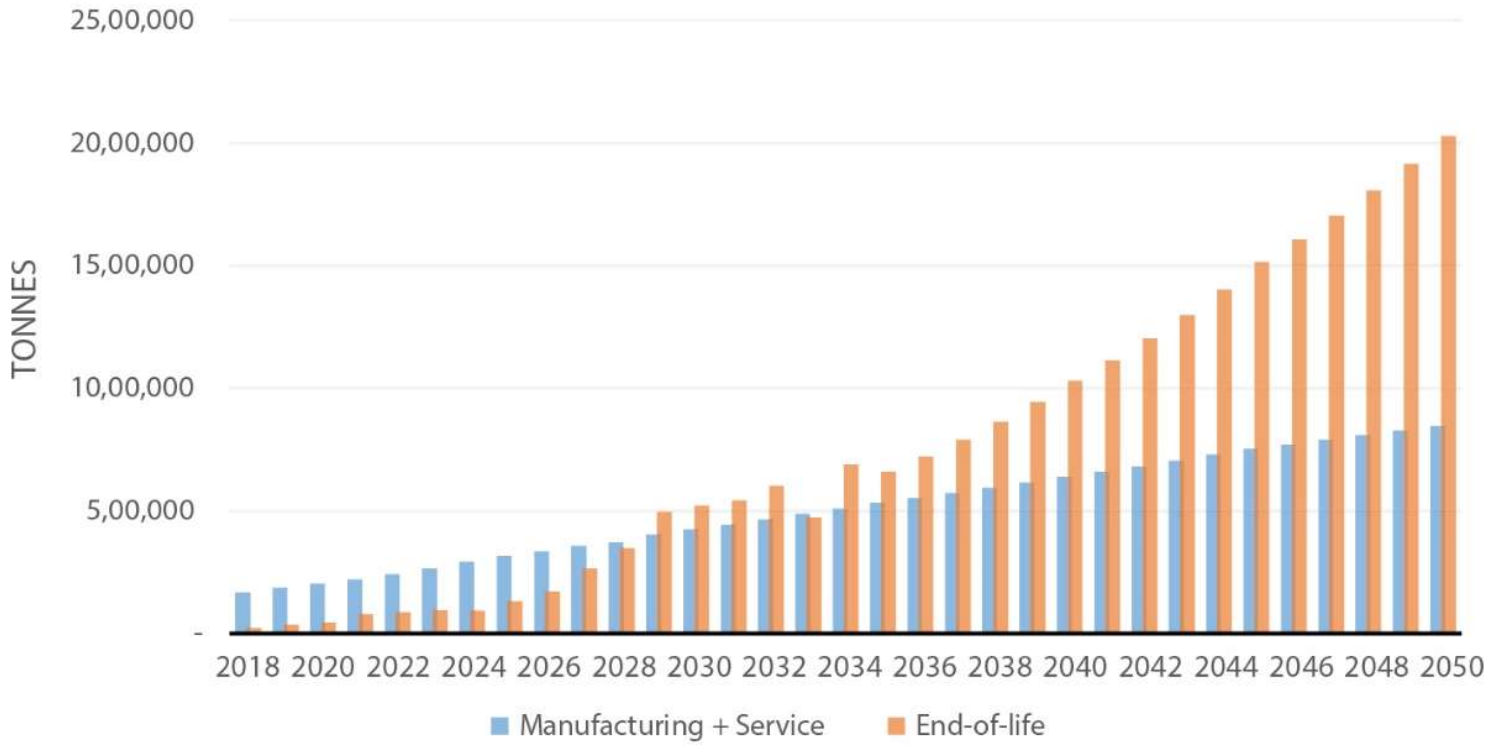




Global Wind Energy Council (GWEC) 2017 Report

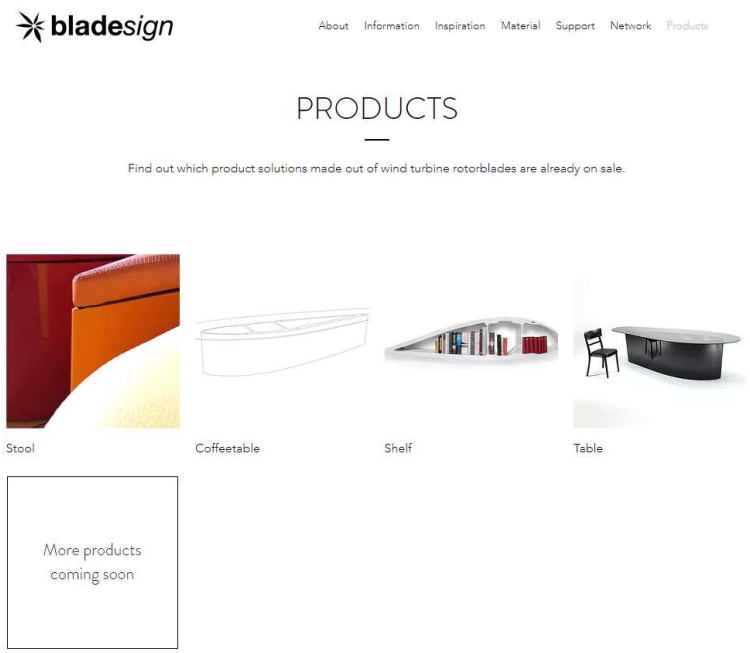
GE 1.5MW turbines of Tappaghan Mountain wind farm

Wind-turbine blade waste



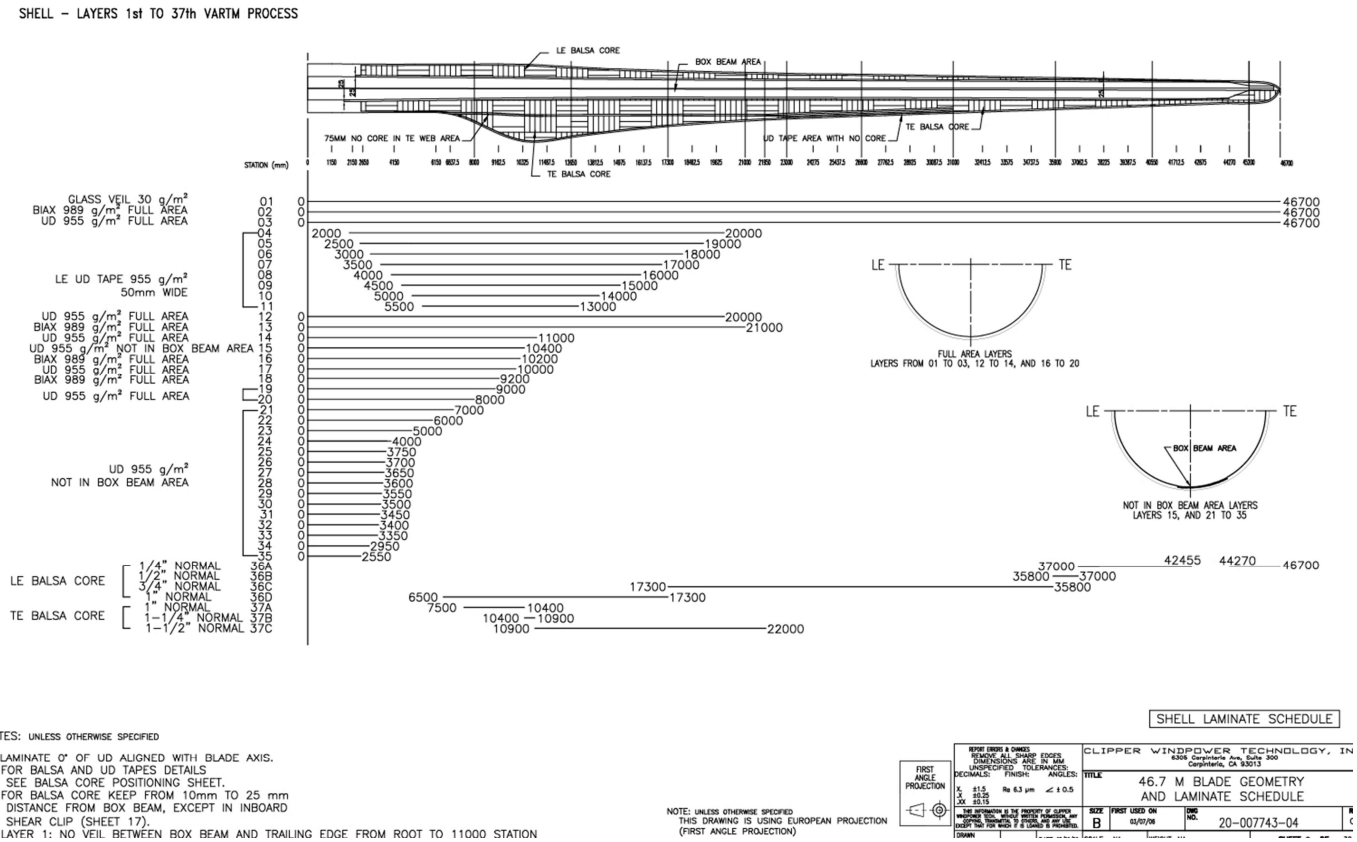
P. Liu, C.Y. Barlow / Waste Management 62 (2017) 229–240

Current wind-turbine blade reuse applications



bladesign.de

Proprietary geometry



NOTES: UNLESS OTHERWISE SPECIFIED

1. LAMINATE 0° OF UD ALIGNED WITH BLADE AXIS.
2. FOR BALSA AND UD TAPES DETAILS SEE BALSA CORE POSITIONING SHEET.
3. FOR BALSA CORE KEEP FROM 10mm TO 25 mm DISTANCE FROM BOX BEAM, EXCEPT IN INBOARD SHEAR CLIP (SHEET 17).
4. LAYER 1: NO VEIL BETWEEN BOX BEAM AND TRAILING EDGE FROM ROOT TO 11000 STATION

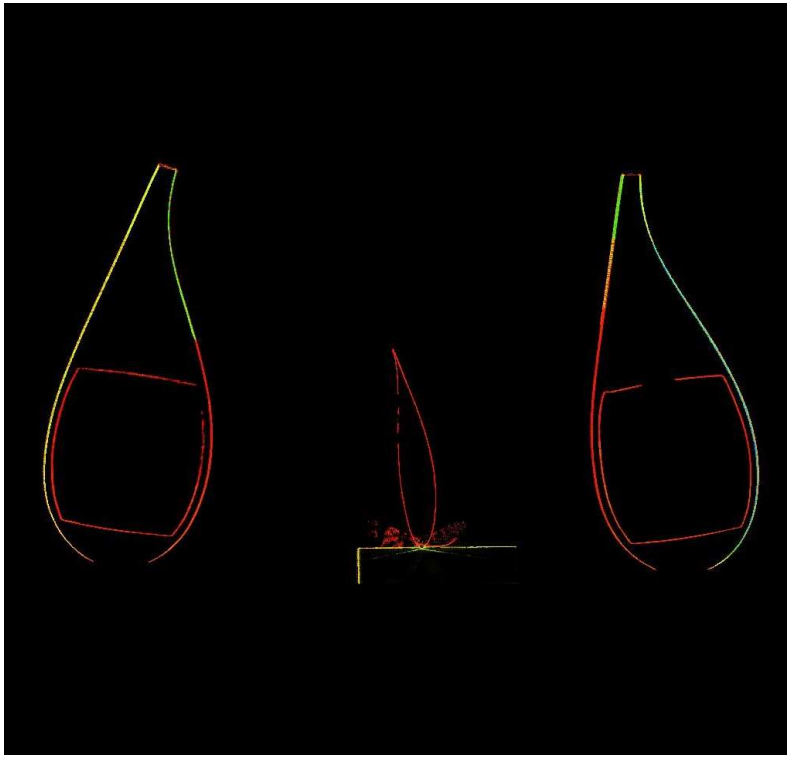
NOTE: UNLESS OTHERWISE SPECIFIED
THIS DRAWING IS USING EUROPEAN PROJECTION
(FIRST ANGLE PROJECTION)

SHELL LAMINATE SCHEDULE

CLIPPER WINDPOWER TECHNOLOGY, IN
TITLE: 46.7 M BLADE GEOMETRY AND LAMINATE SCHEDULE
SIZE: B
DWG NO.: 20-007743-04

Clipper Model C-96 47.6m wind-turbine blade drawing with layup sequence for shell

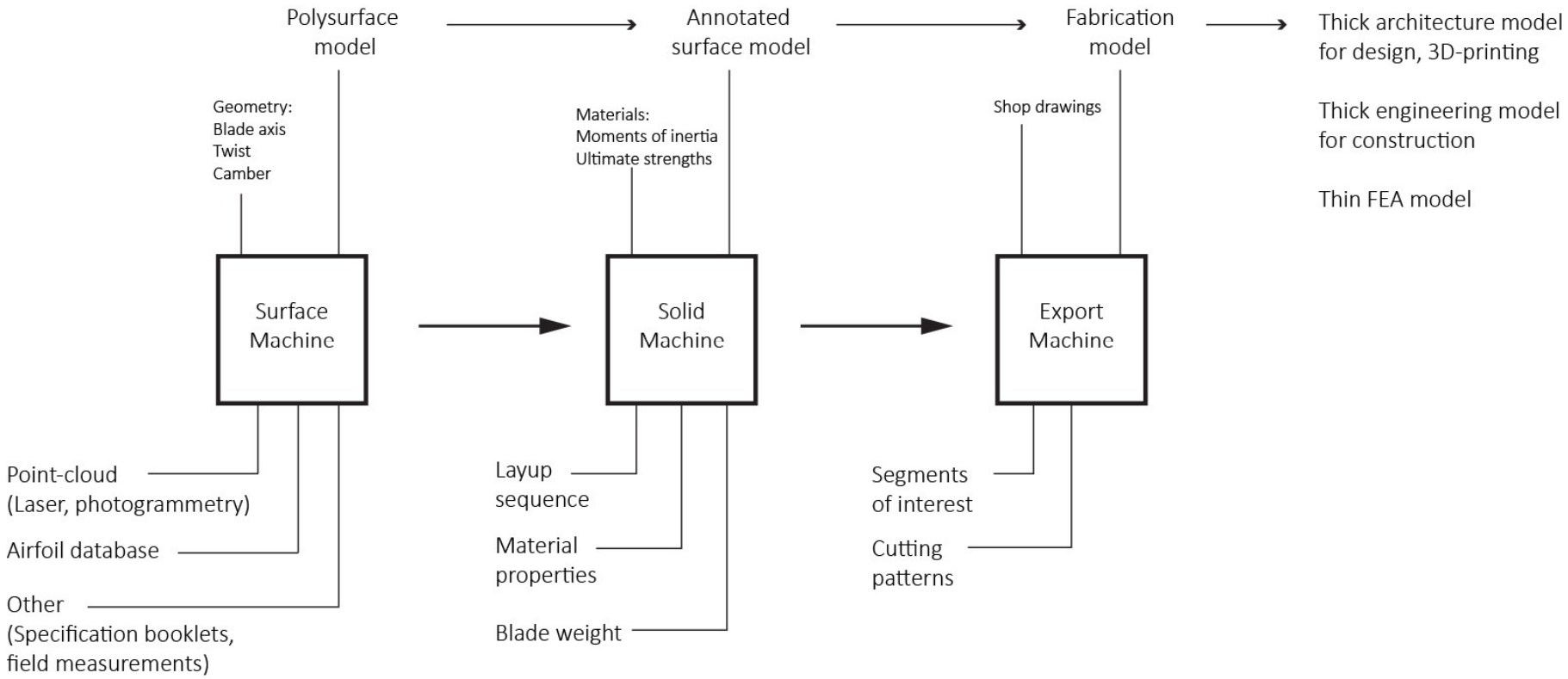
Indirect capture of geometry



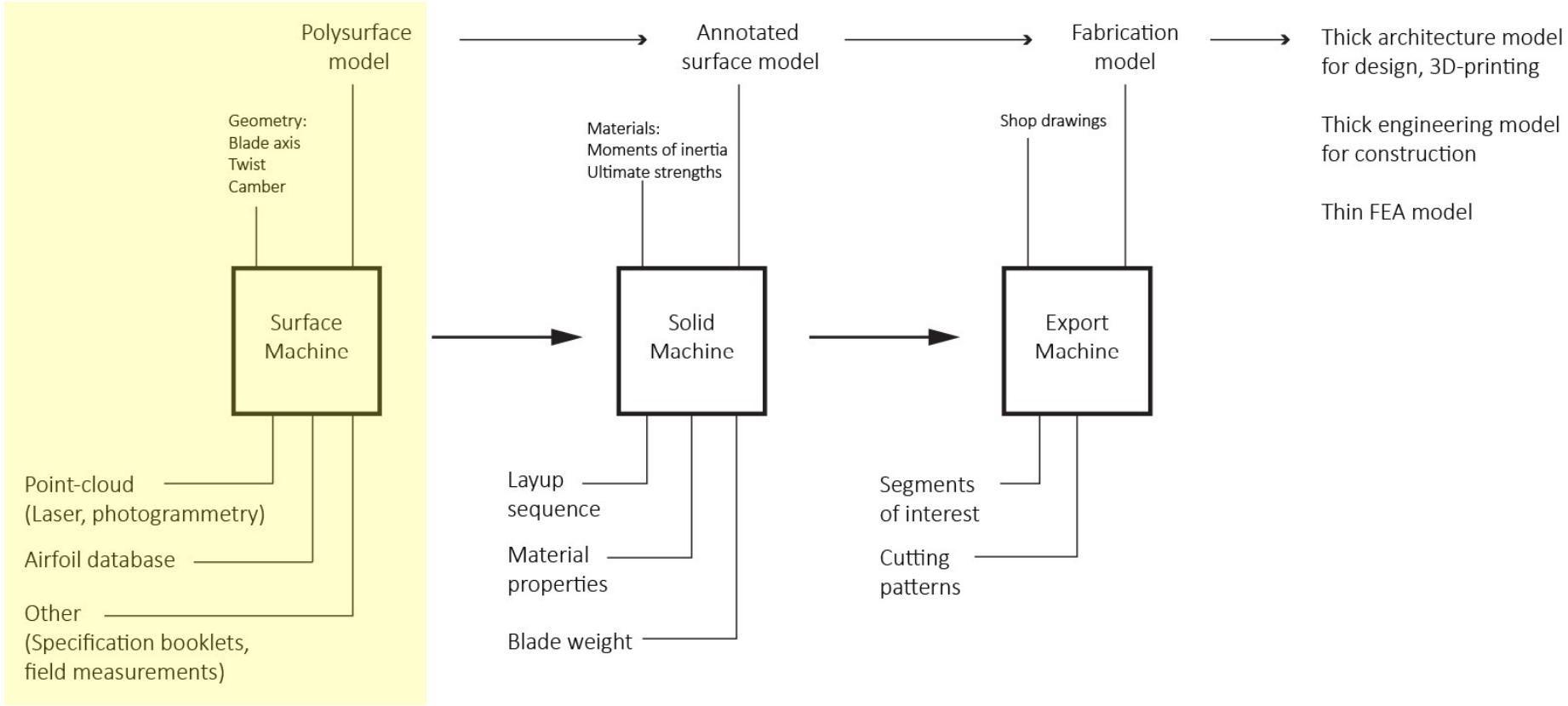
External skin and internal spar boundaries captured in multiple laser scans

Conor Graham of UCC

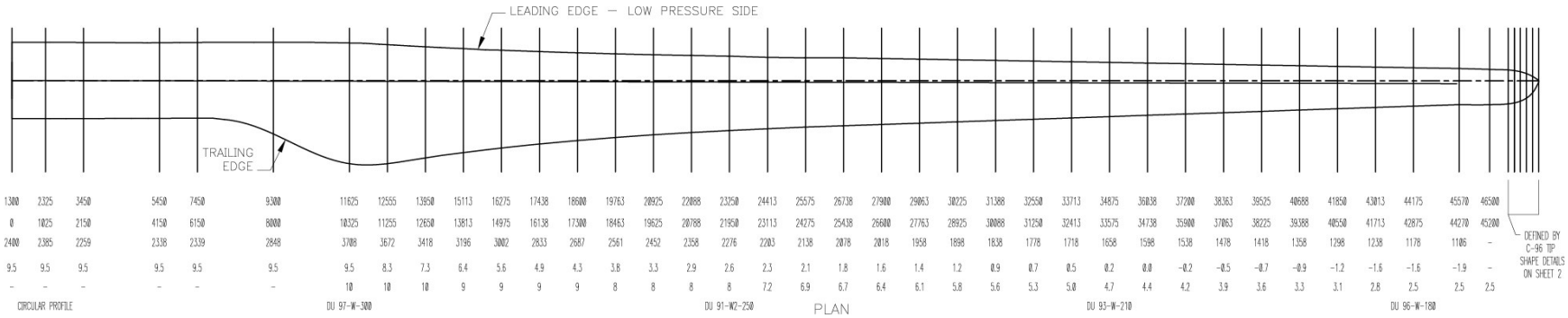
Blade machine concept

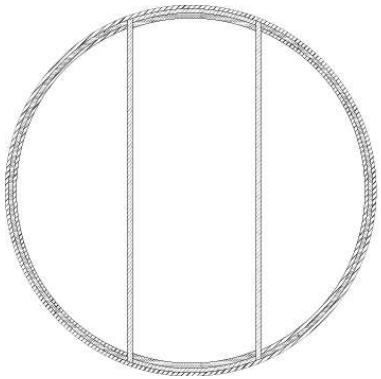


Blade machine concept

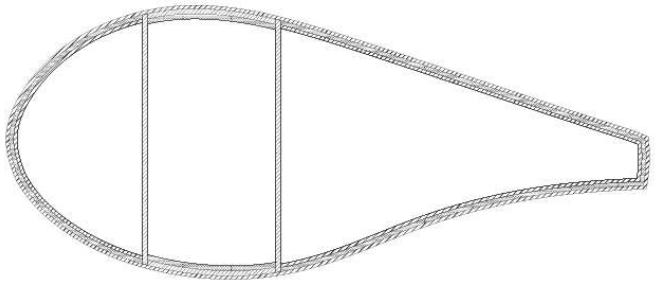


General geometry of blades

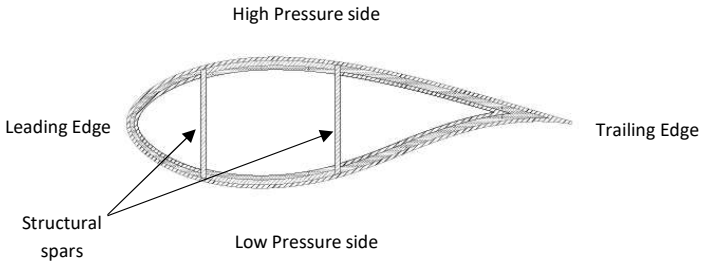




Circular section at root



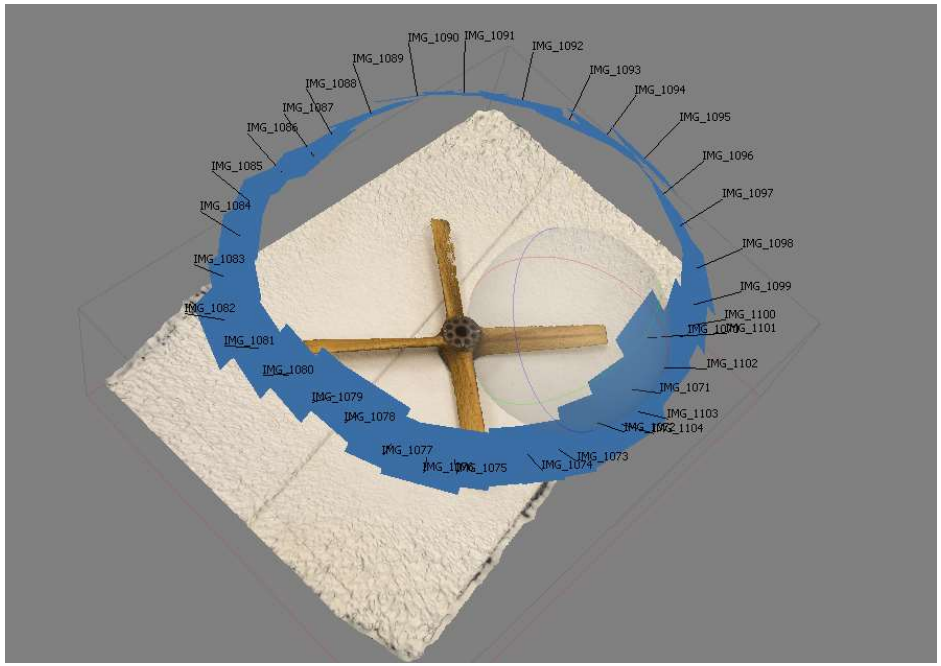
Transitional section



Airfoil section

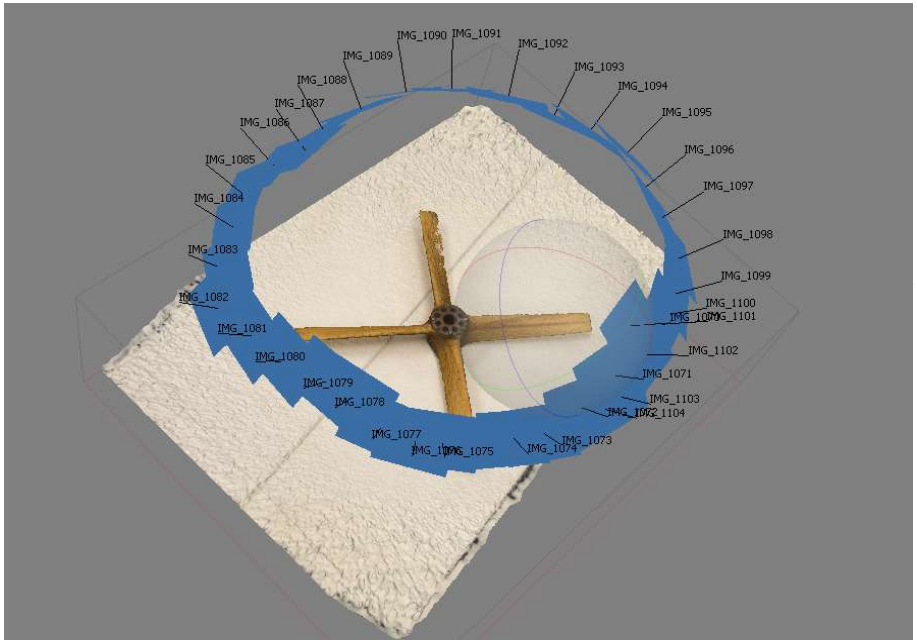
Point cloud production

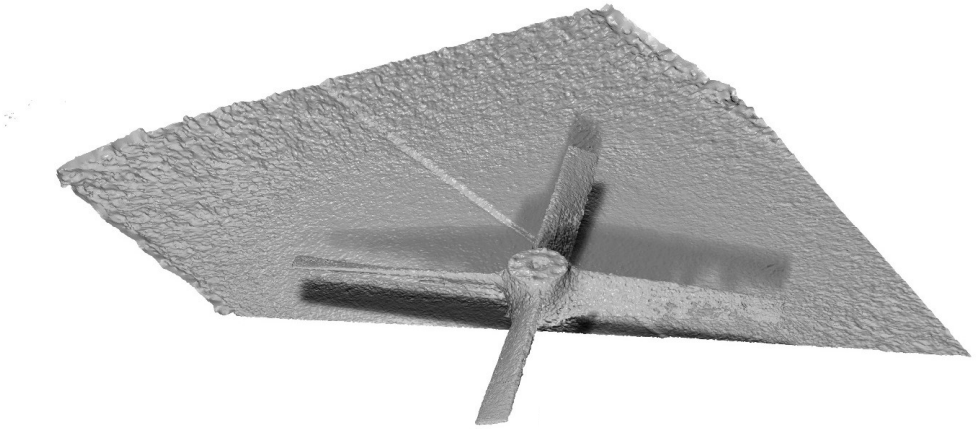
- Photogrammetry
  - Positioning of points in space as observed by multiple lenses equidistant from the object
  - Relatively inexpensive, but requires precise camera placement



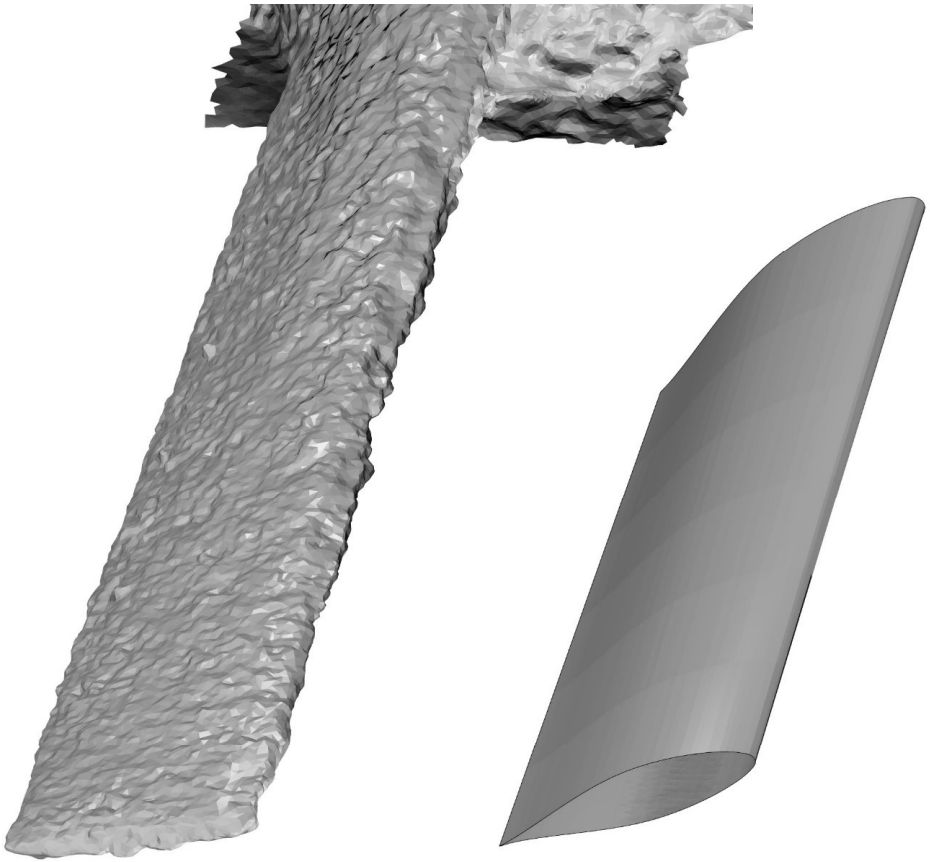
Point cloud production

- Photogrammetry
  - Coarse model built from 32 photographs
  - Able to build mesh and run simple routine to create a surface



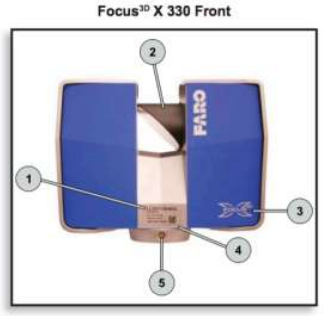


Point cloud production



Point-cloud production

- Laser-scanning

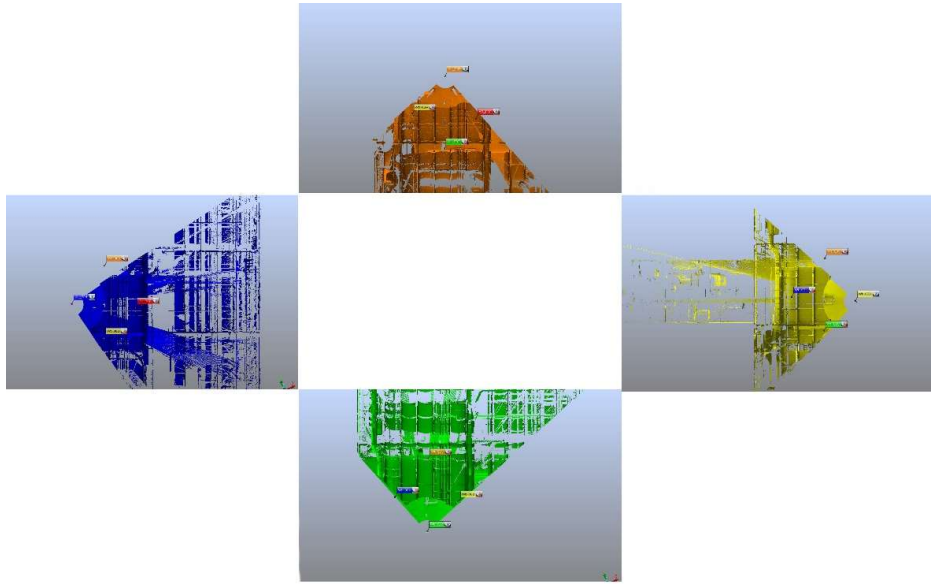


School of Building Construction
Georgia Tech

1. Serial number
2. Mirror
3. Scanner logo
4. Light-emitting diode (LED)
5. Power inlet

Point-cloud production

View from the scanner

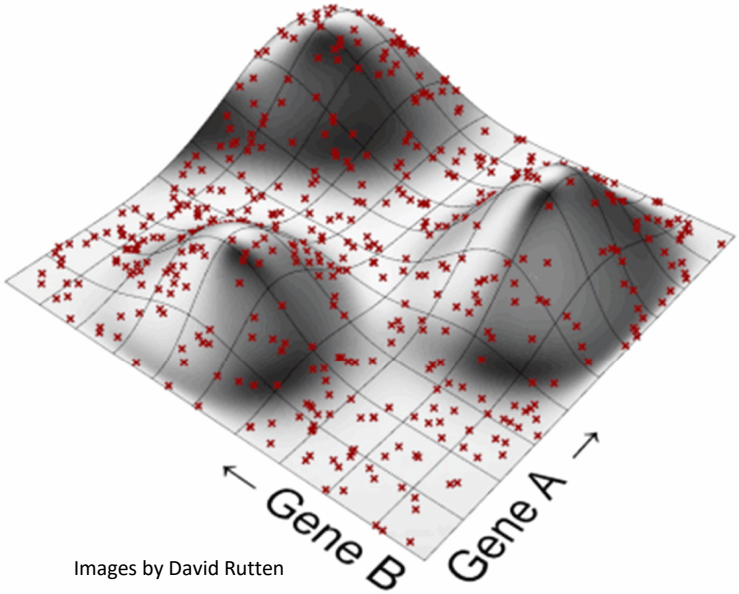


Four scans to capture geometry of exterior skin

Cleaned point cloud

Generating Surfaces from Point Clouds

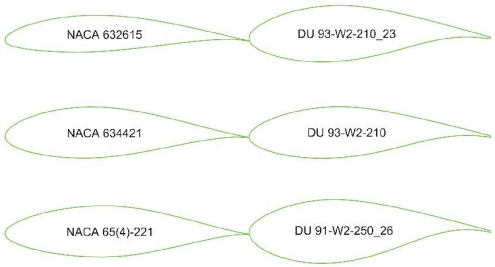
- To build surface geometry from point clouds, a routine is being developed which uses an evolutionary solver to best-fit known airfoil shapes
  - For a given problem, there is a population of **individuals with genomes**
  - As the algorithm runs, individuals **recombine their genomes** and create a new population with a new fitness
  - The **fitness** of an individual's **genomes** is reflected as a **single value optimized** to direct the recombination

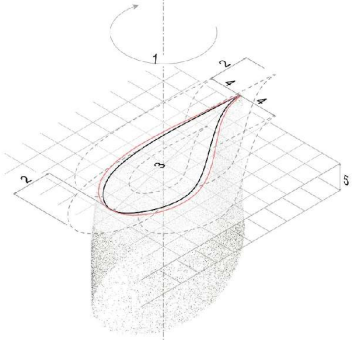


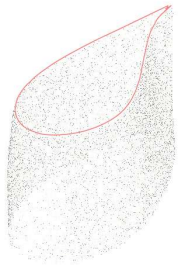
Images by David Rutten

- Gene A controls X-coordinate
- Gene B controls Y-coordinate
- Optimization searches for the largest Z-coordinate possible by manipulating Genes A and B
- Over time, the algorithm produces coordinates with high Z-values

Evolutionary solving applied

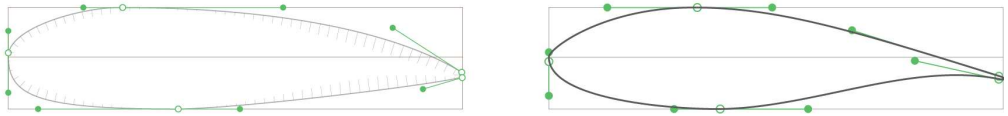






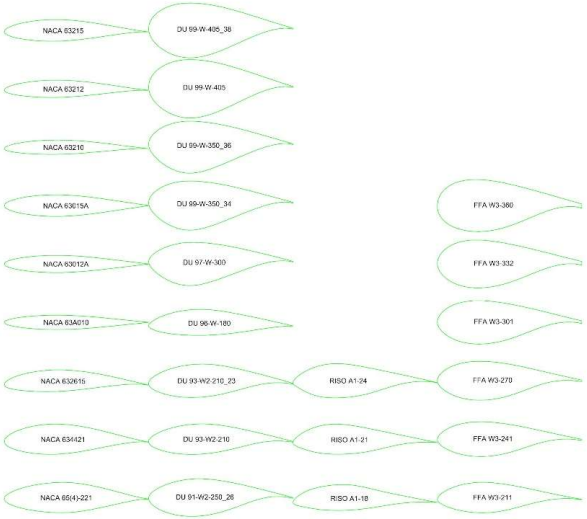
Point cloud cross section

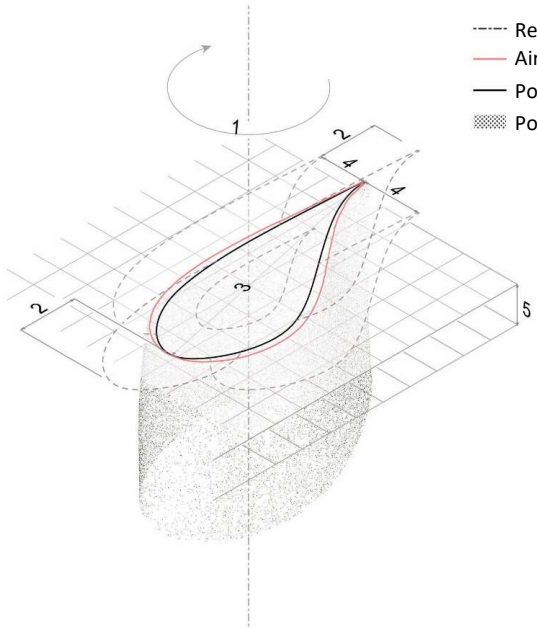
1. Shape-fitting designed airfoil sections

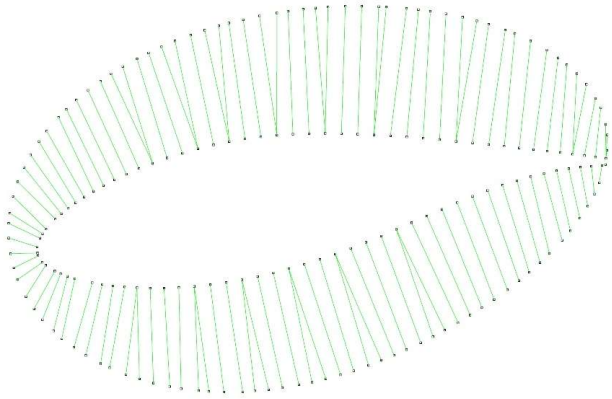


2. Shape-fitting continuous Bezier curves

1. Shape-fitting designed airfoil sections





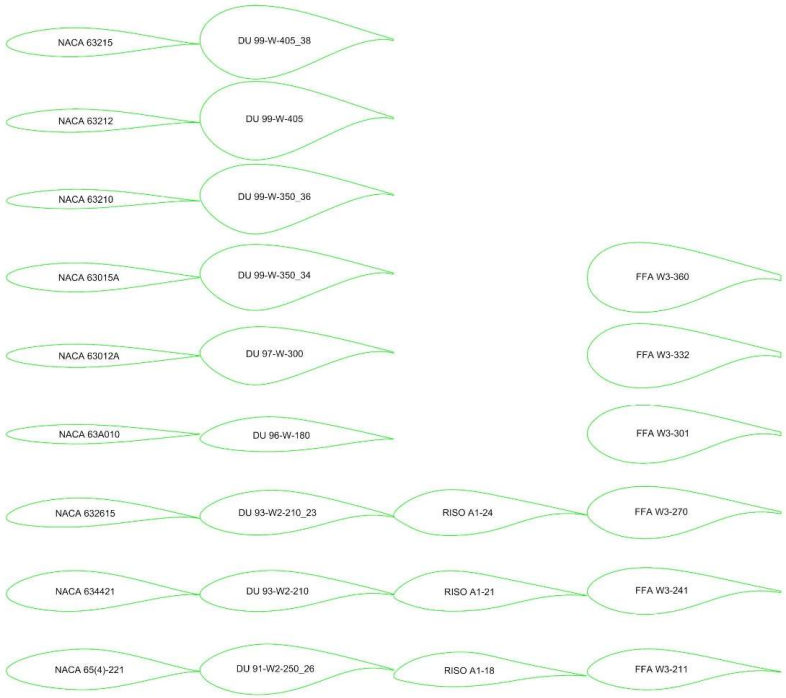


Airfoil shapes

Geometric transformations

Distance minimization

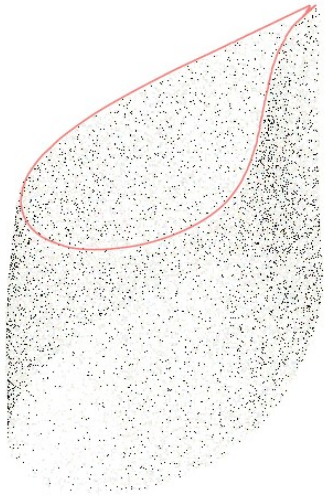
1. Shape-fitting designed airfoil sections



Airfoil shapes

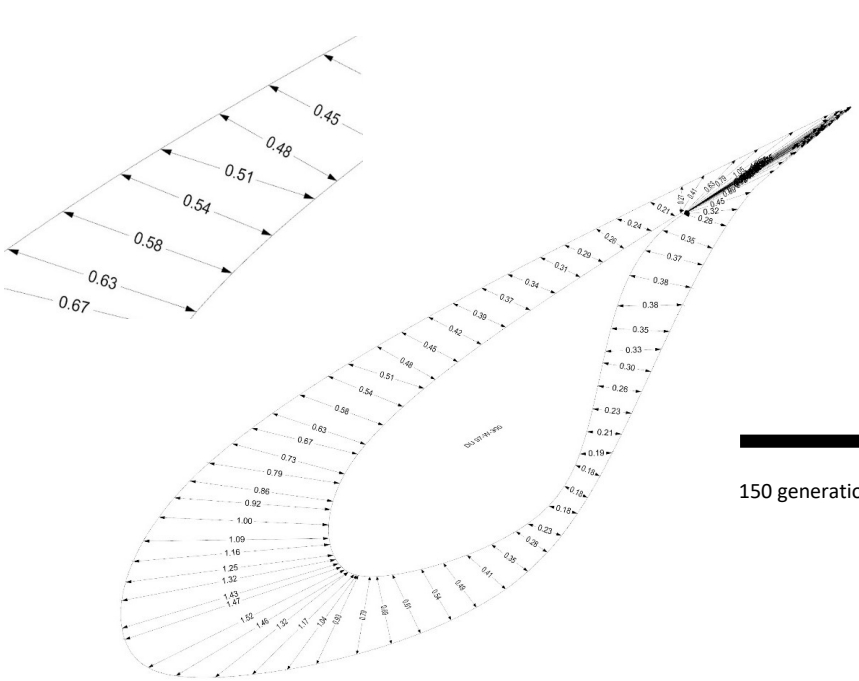
1. Shape-fitting designed airfoil sections

6. Uniform scaling about reference axis
5. Rotation about reference axis
4. Y-translation
3. X-translation
2. Plane creation
1. Point-cloud section

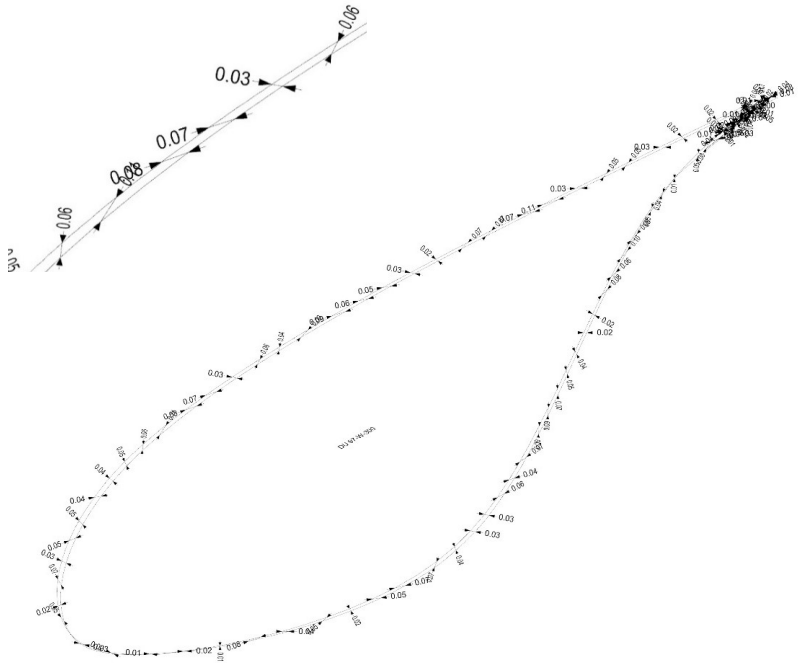


Geometric transformations

1. Shape-fitting designed airfoil sections



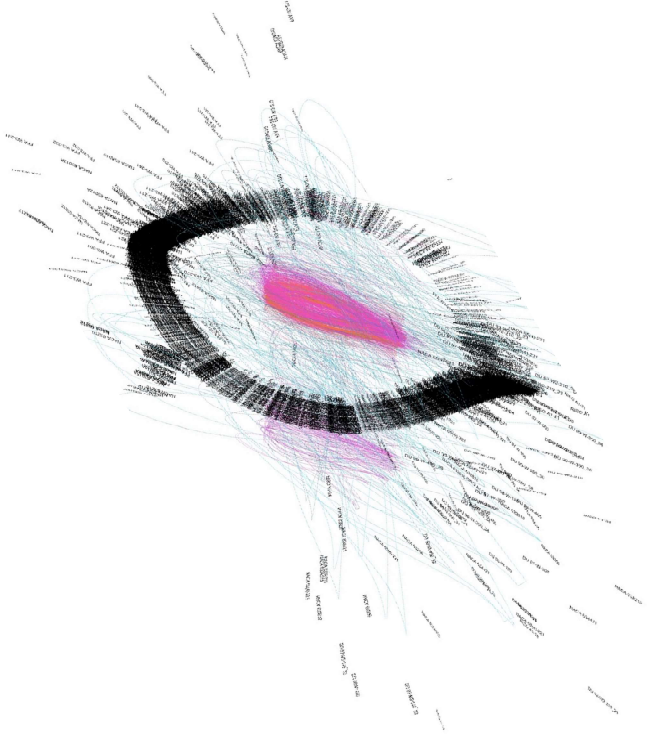
150 generations, 7500 individuals



Start condition

End condition

1. Shape-fitting designed airfoil sections

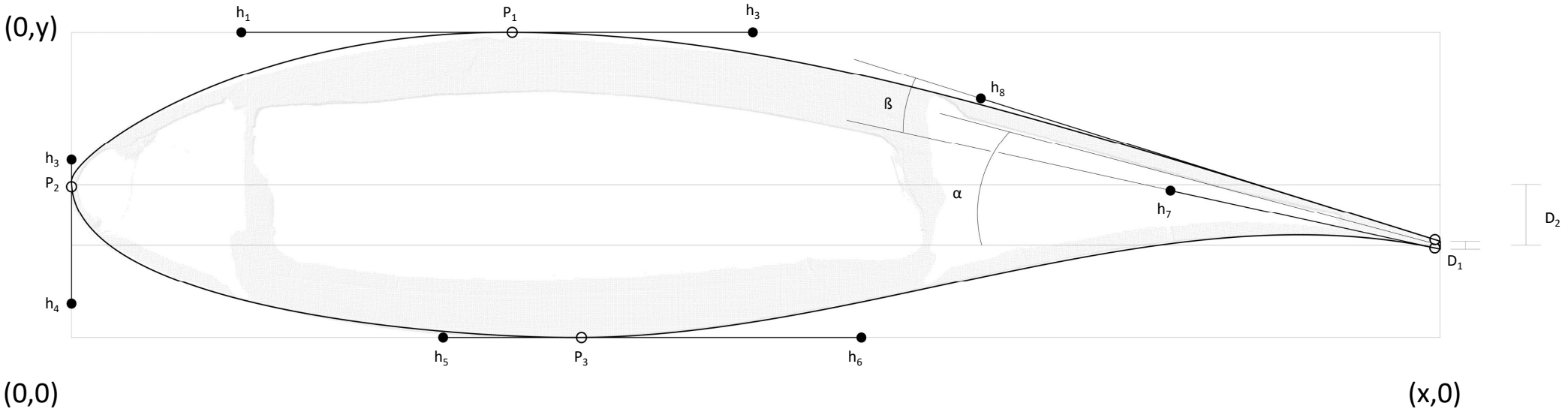


Tracking the solver's progress at each plane

Point-cloud of the Clipper C-96 47.6m blade from 115' to 142'

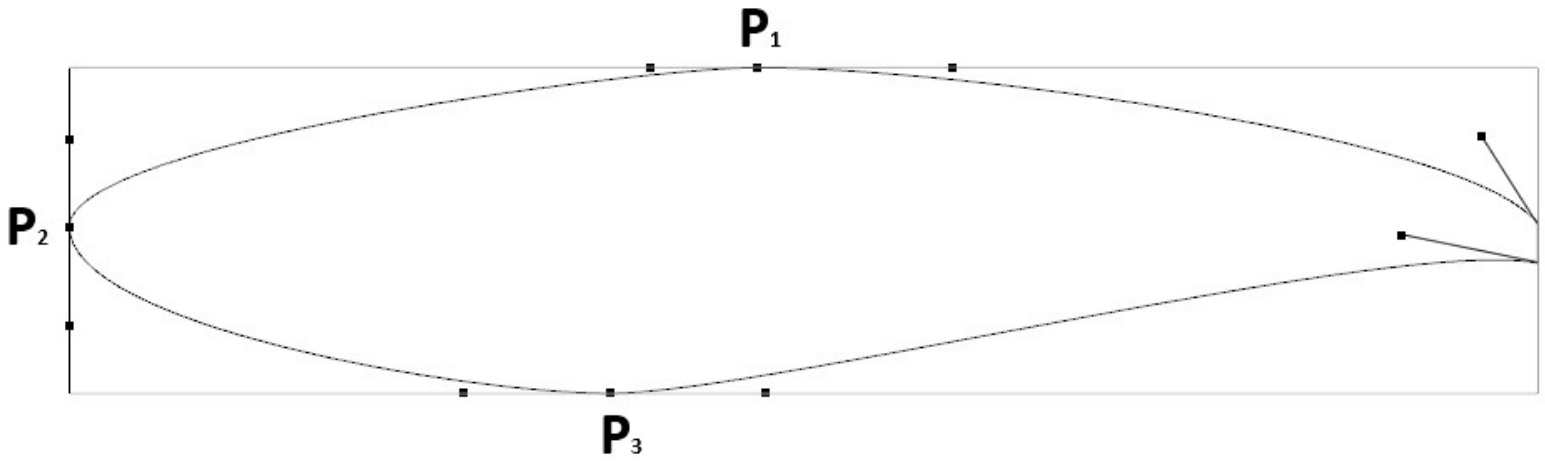
Rebuilt surface of the Clipper C-96 47.6m blade from 115' to 142'

2. Shape-fitting continuous Bezier curves



Four continuous Bezier curves manipulated to fit silhouette of point-cloud

2. Shape-fitting continuous Bezier curves



$\mathbf{P_x}$ and $\mathbf{D_x}$ are start points for the curves

$\mathbf{h_x}$ are the tangent "handles" that change the curvature of each curve

2. Shape-fitting continuous Bezier curves

Point-cloud of the Clipper C-96
47.6m blade from 115’ to 142’

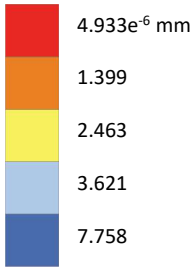
Exterior surface rebuilt from interpolated Bezier curves

2. Shape-fitting continuous Bezier curves

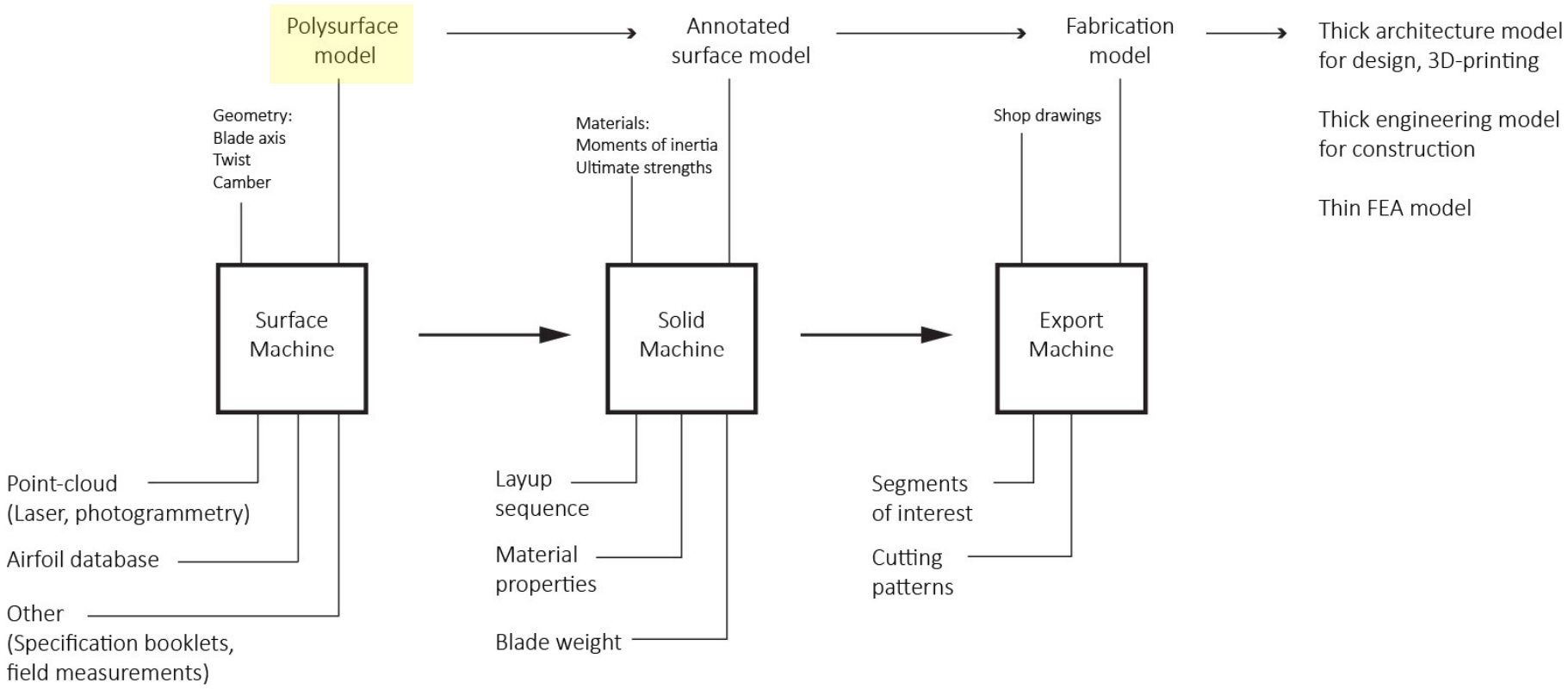
Point-cloud of the Clipper C-96 47.6m blade from 115’ to 142’

Exterior surface rebuilt from interpolated Bezier curves

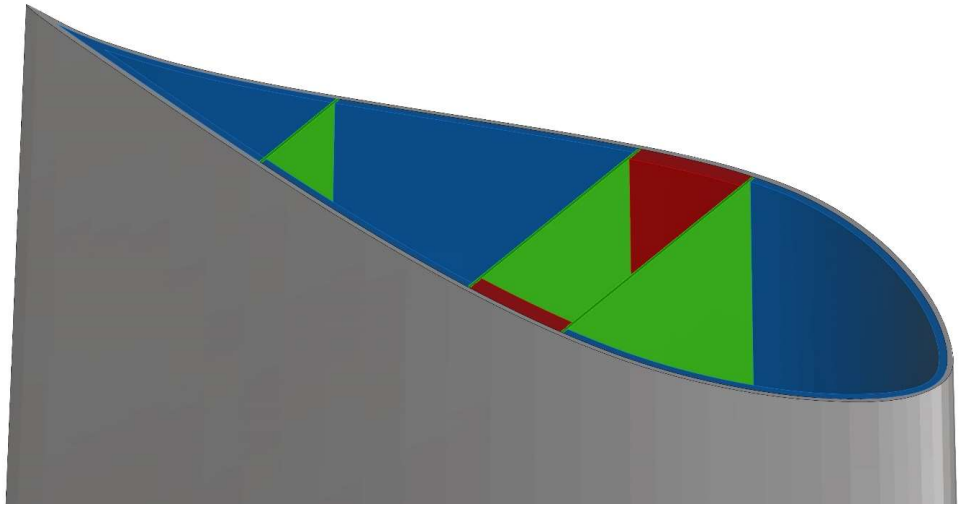
Mean deviation between point-cloud and surface model



Downstream applications

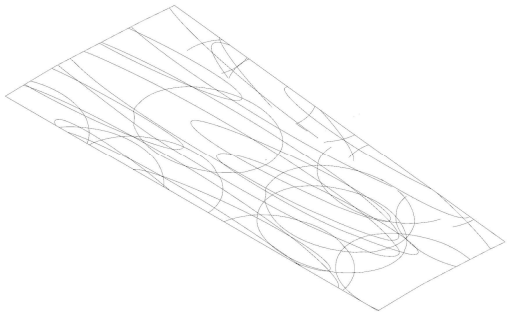


Downstream applications



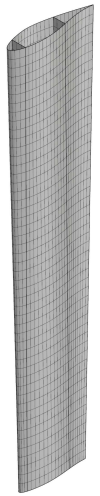
Thick model can be generated with material property data

Downstream applications



Graphic patterns

Connection sockets



FE Mesh

Next steps

- Predict airfoil from Bezier curves?
- Non-linear segments of the blade?
- Incomplete scans (?)
  - i.e. if we could only take one scan, say from a drone, how would we position the blade to capture the most useful point cloud?
- Using color data of laser scans?