Possibilities and challenges of measuring small fibre composite system structures using terrestrial laser scanning

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Collaboration, Innovation and Resilience: Championing a Digital Generation

Brisbane, Australia 6–10 April

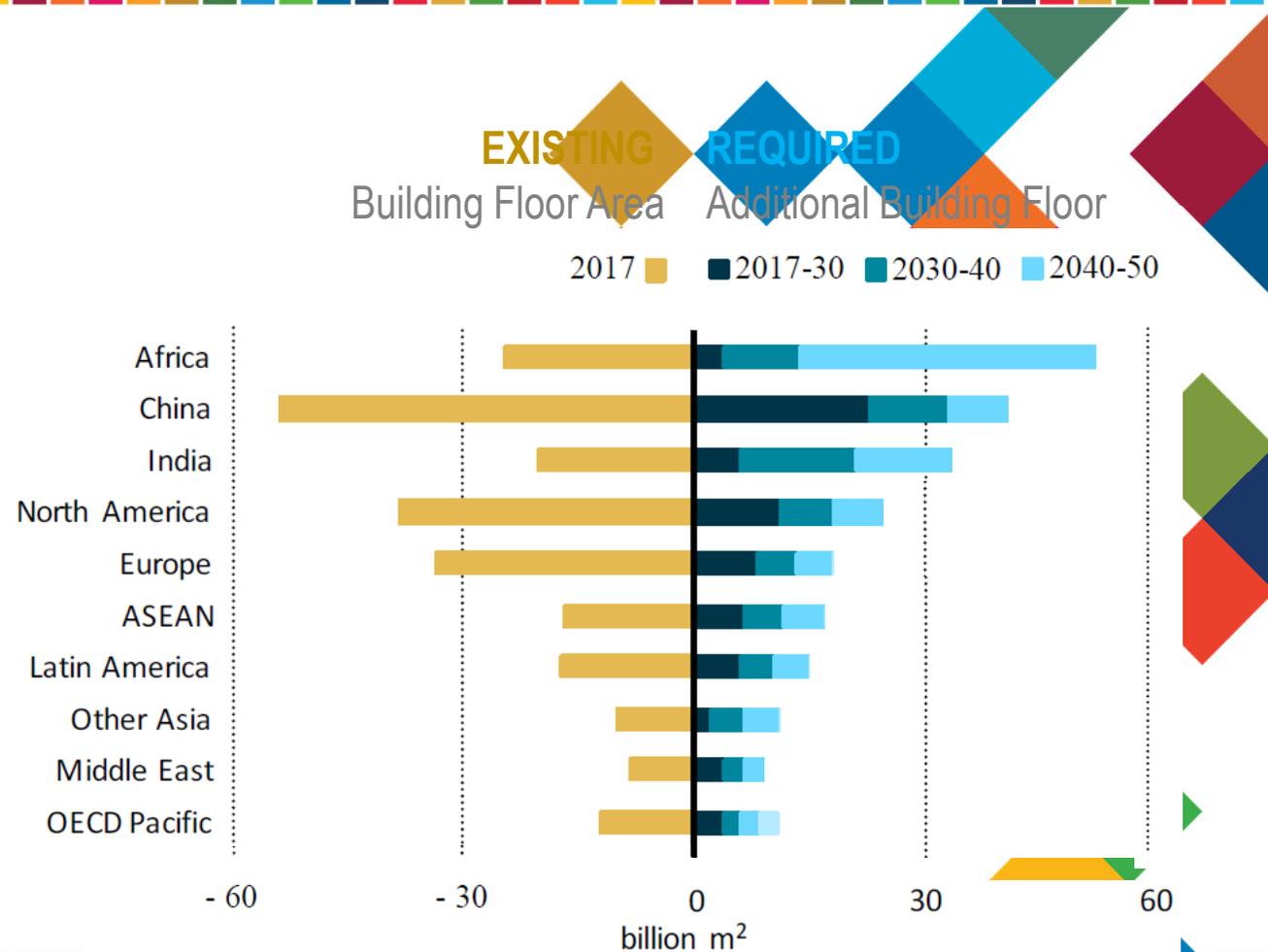ORGANISED BY · PLATINUM SPONSORS

Outline

- Motivation

- Principles of coreless filament winding

- Test setup and scanners

- Evaluation

  – Comparison of laserscanners

  – Influence of material

  – Intensities at "edge" areas

- Conclusion and outlook

Motivation

GRAND CHALLENGE:

- Urban population growth:
  2.6 billion people until 2050

- Building floor area:
  needs to be almost *doubled*

- Required construction:
  65.000 m² / h for 3 decades

EXISTING
Building Floor Area

REQUIRED
Additional Building Floor

Legend: 2017 | 2017-30 | 2030-40 | 2040-50

Regions (top to bottom): Africa, China, India, North America, Europe, ASEAN, Latin America, Other Asia, Middle East, OECD Pacific

X-axis: -60, -30, 0, 30, 60 — billion m²

(SOURCE: UNITED NATIONS ENVIRONMENT – GLOBAL STATUS REPORT 2017)

Principles of coreless filament winding

- Fibre-reinforced polymers (FRP) are used since many years for structural applications in industries like automotive, aeronautics or ship-building

- Carbon fibres have a low thermal expansion, a high corrosion resistance and a high strength to weight ratio

- Developments in the robotic fabrication makes the design based on a fibre-fibre interaction instead of expensive formworks possible

- Monitoring of fibre geometry (position, orientation and cross-section is needed)

→ **Is it possible to monitor the fibres geometry using TLS and what are the requirements for the measurement device?**
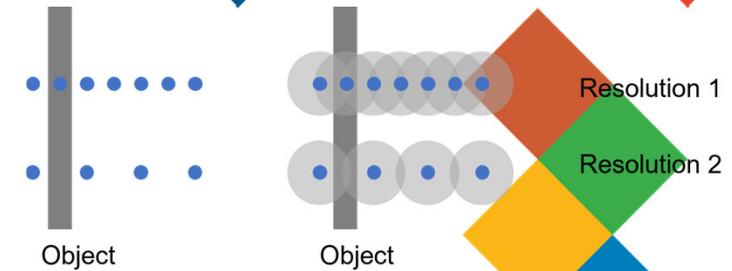
Fibre width: approximately 1-2 cm

Test setup and scanners

- Investigation of surface
  - Use of AESUB scanning spray
- 3 different laserscanners
  - Trimble X7 (pulse-scanner)
 - Leica HDS7000 (phase-shift scanner)
  - RieglVZ2000 (pulse-scanner)

	Resolution at 3 m	Footprint size	Points on the object	Points with part of the spot on the object
Leica HDS7000	1.8 mm	4.4 mm	5	8
Trimble X7	1.5 mm	4.4 mm	6	9
Riegl VZ2000	2.1 mm	19.8 mm	4	14

Resolution 1

Resolution 2

Object   Object

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Evaluation – Comparison of Laserscanners

- Mixed-pixel effect can be detected for Leica HDS7000 scans → phase-shift scanner
- Nothing comparable with Trimble X7 and RieglVZ2000

80 cm   80 cm   80 cm   80 cm
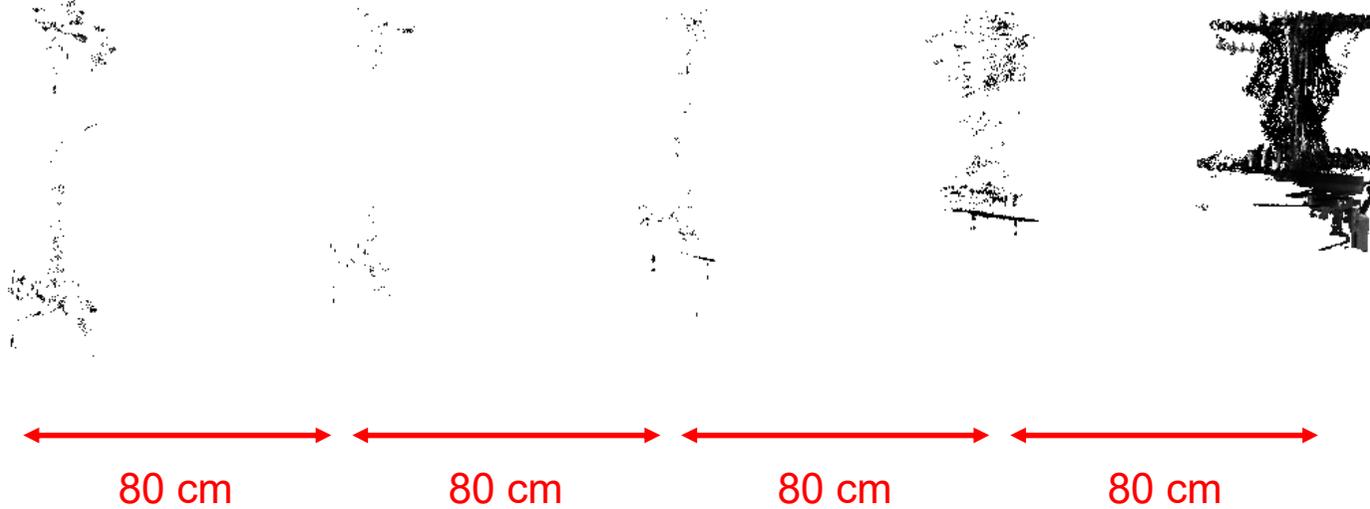
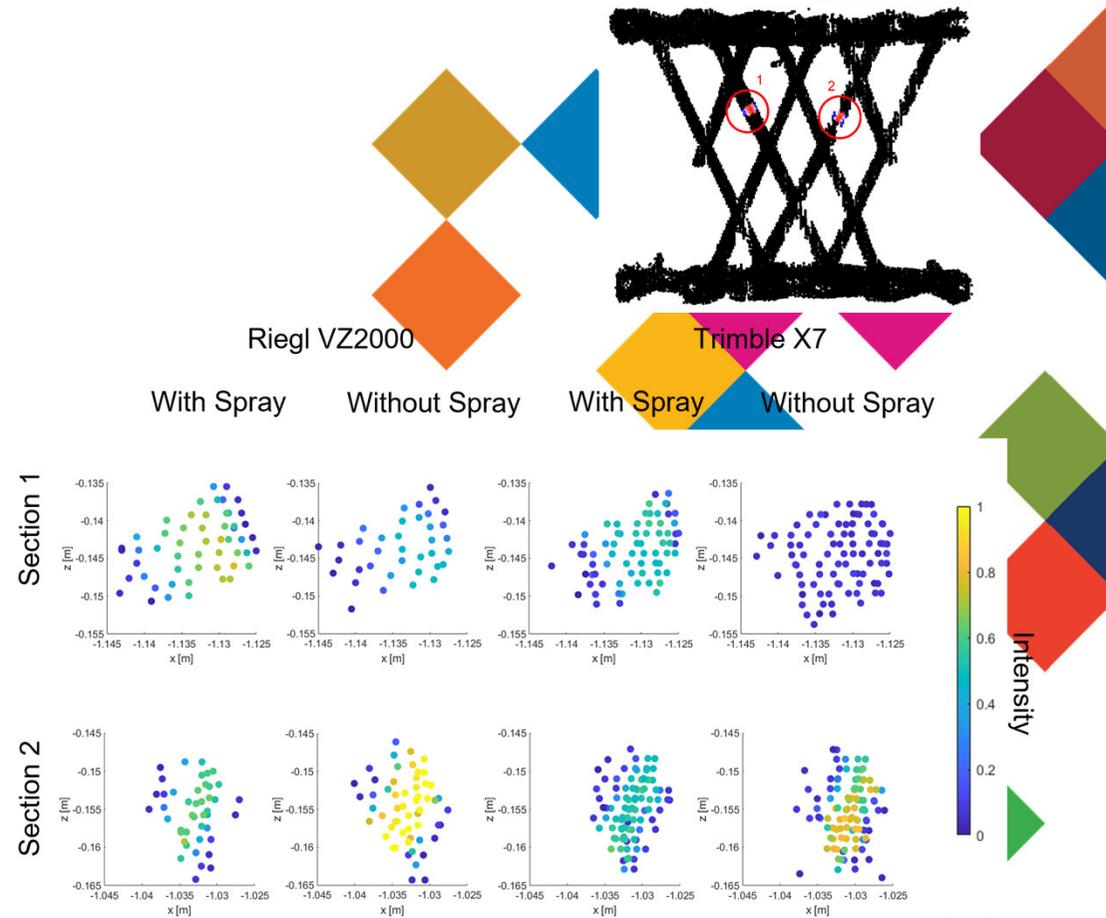# Evaluation – Comparison of Laserscanners and Influence of Material

- Complete detection of the object only possible with Trimble X7 without scanning spray

- Thinner segments especially for Leica HDS7000

- Improvements of completeness with spray for Leica HDS7000 and RieglVZ2000

- Decreasing intensities towards the edge of the object especially with scanning spray
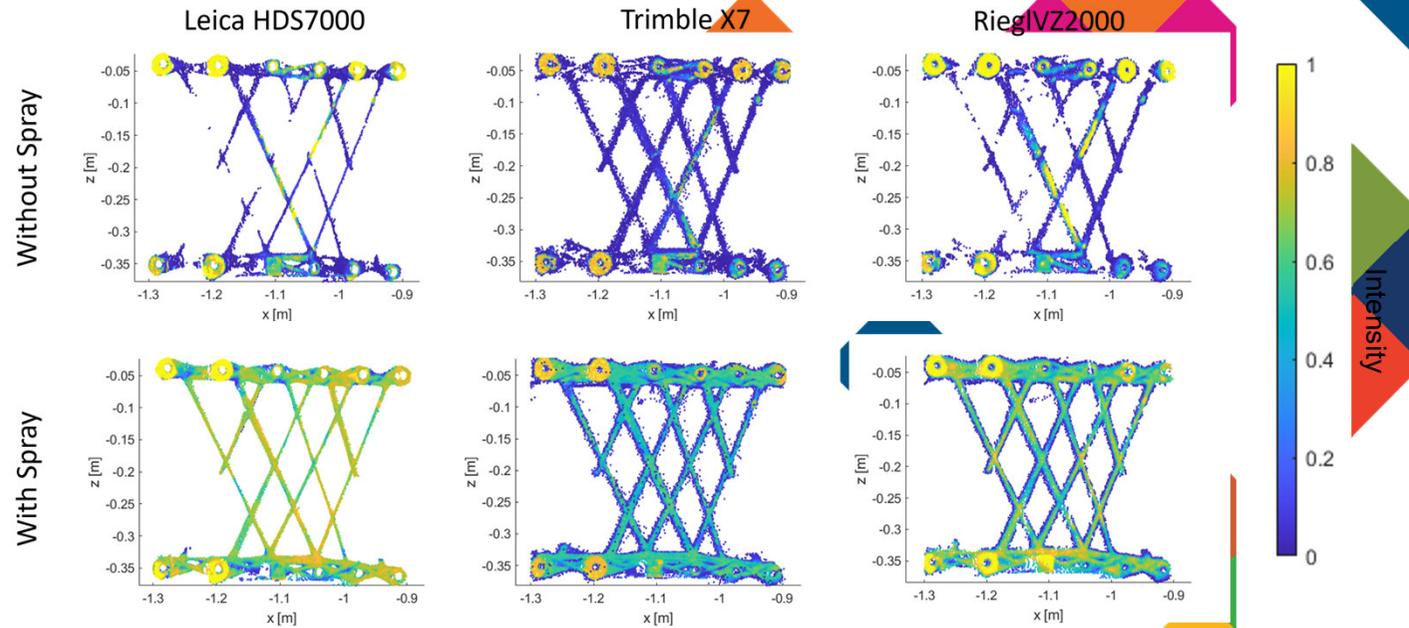
→ **Phase-shift scanner (Leica HDS7000) is not suitable for this task, further investigations for Trimble X7 and RieglVZ2000**

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Evaluation - Intensities at "edge" areas

- Decreasing intensities towards the edge can be detected in almost all scenarios
- Stronger differences using the scanning spray
- Section 2: Edge is more clearly defined
  - Perpendicular measurements
- Size of the point cloud differs with and without scanning spray

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Conclusion

- It is possible to detect individual fibre bundles using TLS

- Quality and completeness is highly dependent on used scanner

- Pulse scanner with small footprint are best suited for this task

- In this study Trimble X7 performs best

- Completeness improved with scanning spray

- Measurements without scanning spray fit better with the expected geometry

Outlook

- Investigation of several instrument points

- Use of reference generated with industrial measurement system like a light strip projector
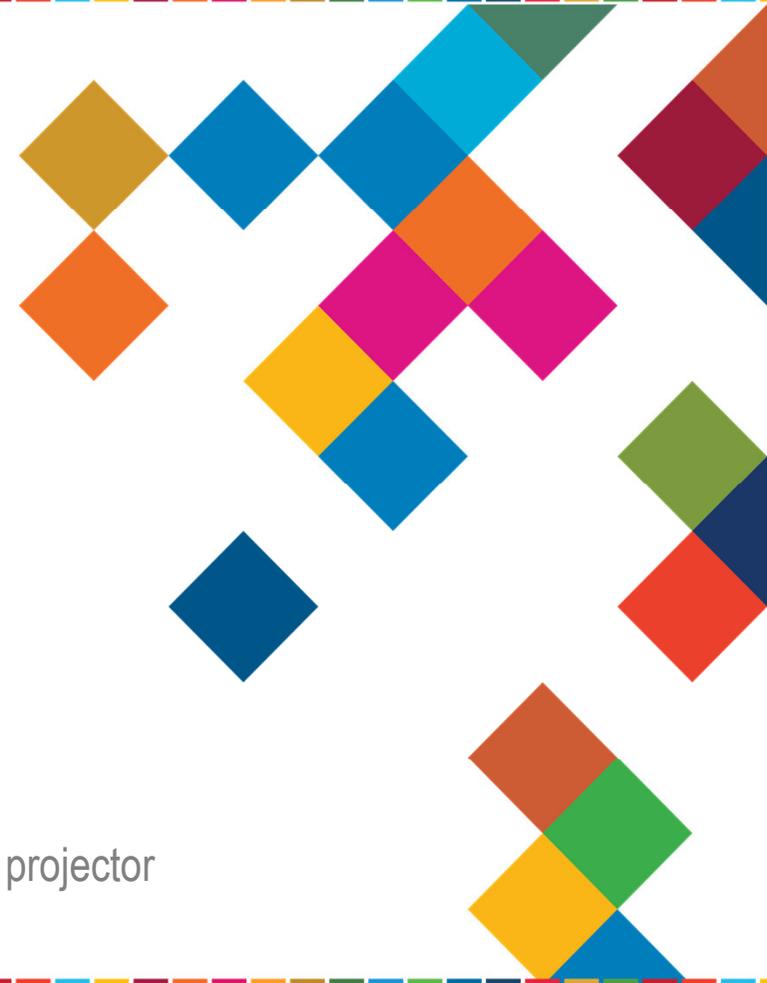
Thank you for your attention!

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Motivation

DIGITAL TECHNOLOGIES:

- **Adoption is slow and incremental**

- **Construction least digital of all industries**

(SOURCE: BEA; BLS; US CENSUS; IDC; GARTNER; MCKINSEY)

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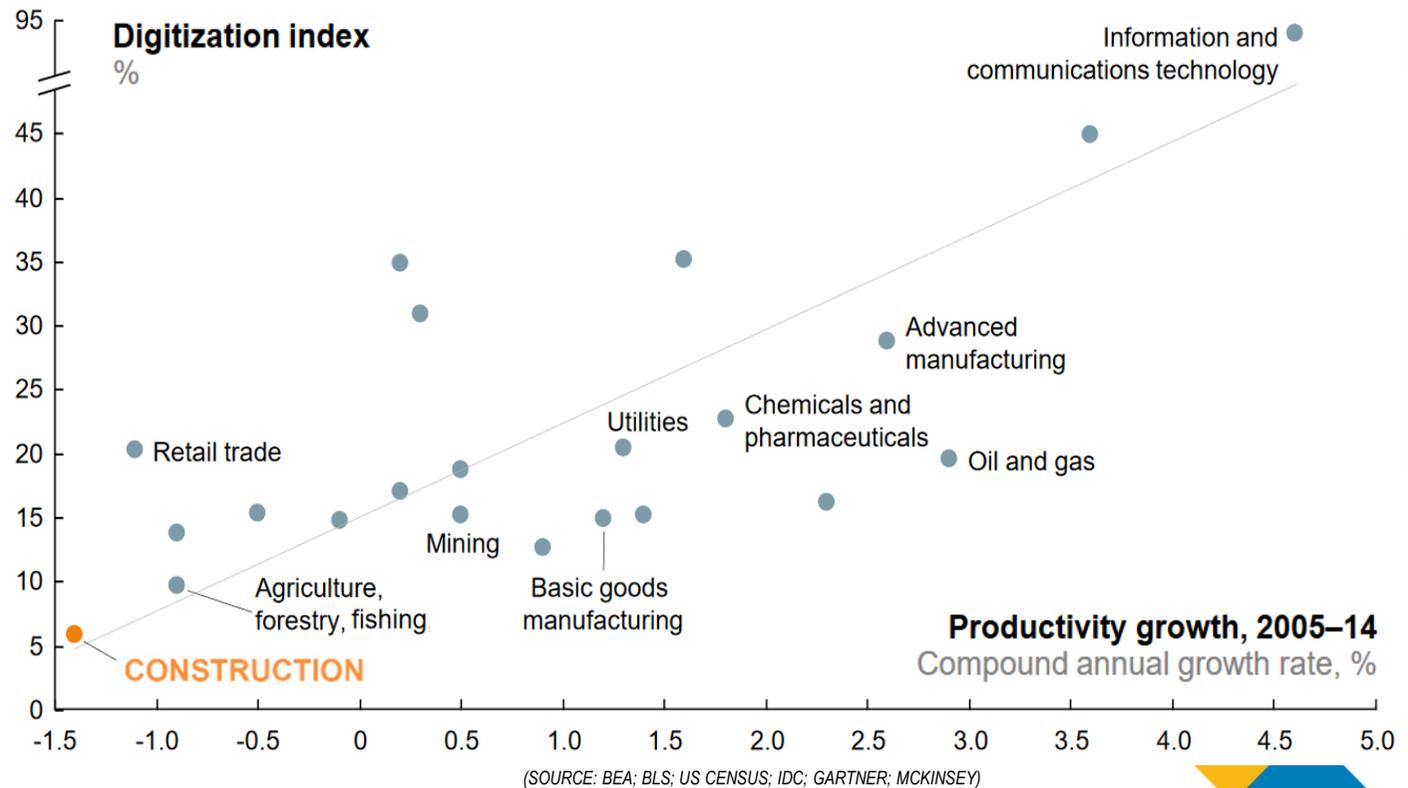
ECOLOGICAL CHALLENGE:

- *Greatest impact: Building sector causes*
  - *40% of global resource consumption*
  - *40% of energy use*
  - *50% of global waste*

ECONOMIC RELEVANCE:

- *Biggest industry: world-wide and in Germany*
- *Prospect of enormous future growth*

SOCIO-CULTURAL IMPORTANCE:
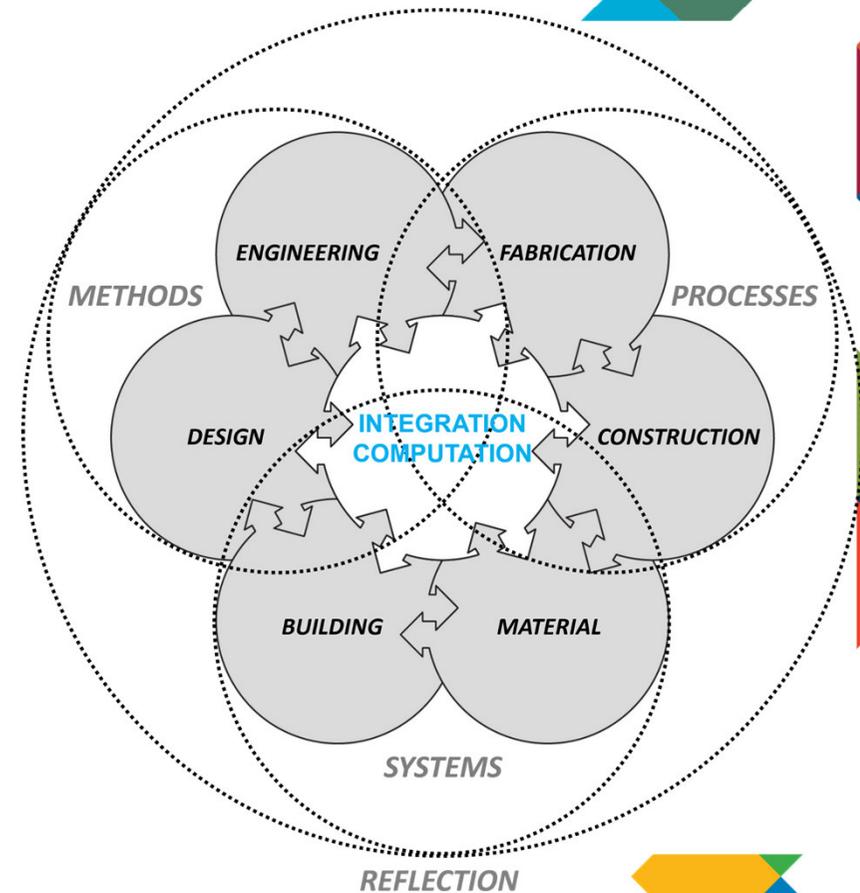
- *Humans spend 87% of their lifetime in buildings*
- *Direct and long-lasting impact on quality of life*
- *Important cultural contribution*

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Motivation

➤ *Harness full potential of digital technologies for game-changing innovation*

- *Computational design and engineering METHODS:*
  >> ENABLE INTEGRATION

- *Cyber-physical robotic fabrication and construction PROCESSES:*
  >> IMPROVE PRODUCTIVITY

- *Effective, truly digital material and building SYSTEMS:*
  >> ENHANCE SUSTAINABILITY

- *ENVIRONMENTAL, SOCIO-CULTURAL AND ETHICAL REFLECTION*

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Evaluation – Comparison of Laserscanners and Influence of Material

- Comparable effects for turned object
- Incomplete detection for RieglVZ2000 without scanning spray
  - only a quarter of points can be detected without the scanning spray

→ Phase-shift scanner (Leica HDS7000) is not suitable for this task, further investigations for Trimble X7 and RieglVZ2000
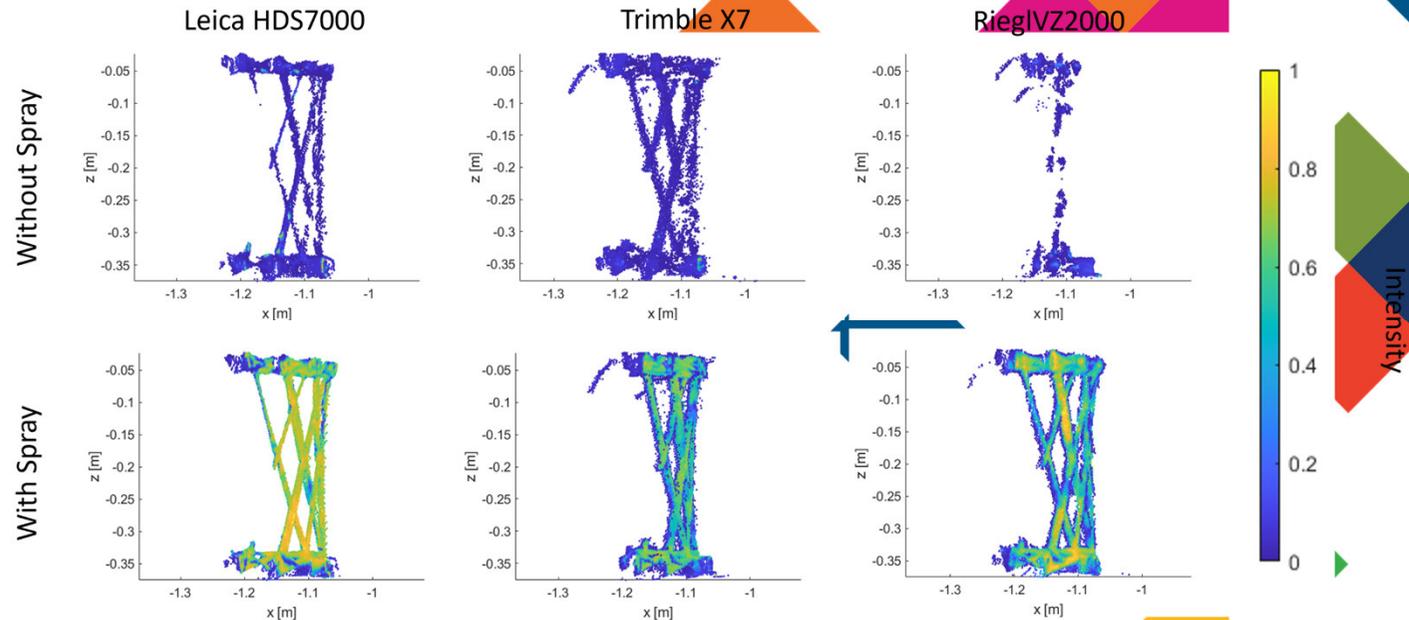
Evaluation - Intensities at "edge" areas

- Background for Trimble X7

- Difference varies within the object

- Approximately 2 points difference on each edge

  - Results in change of up to 6 mm for both sides