



AKADEMIA GÓRNICZO-HUTNICZA  
IM. STANISŁAWA STASZICA W KRAKOWIE

# Photogrammetry and Remote Sensing

**Lecture : TLS - Terrestrial Laser Scanning**

**dr inż. Sławomir Mikrut**



## Schedule

- Three films – one question ?
- Features
- How laser scanning works
  - Time of flight
  - Phase Shift
- Operation
- Hardware (Riegl, Leica, Faro)
- Applications
- Integration
- Some projects



## Features

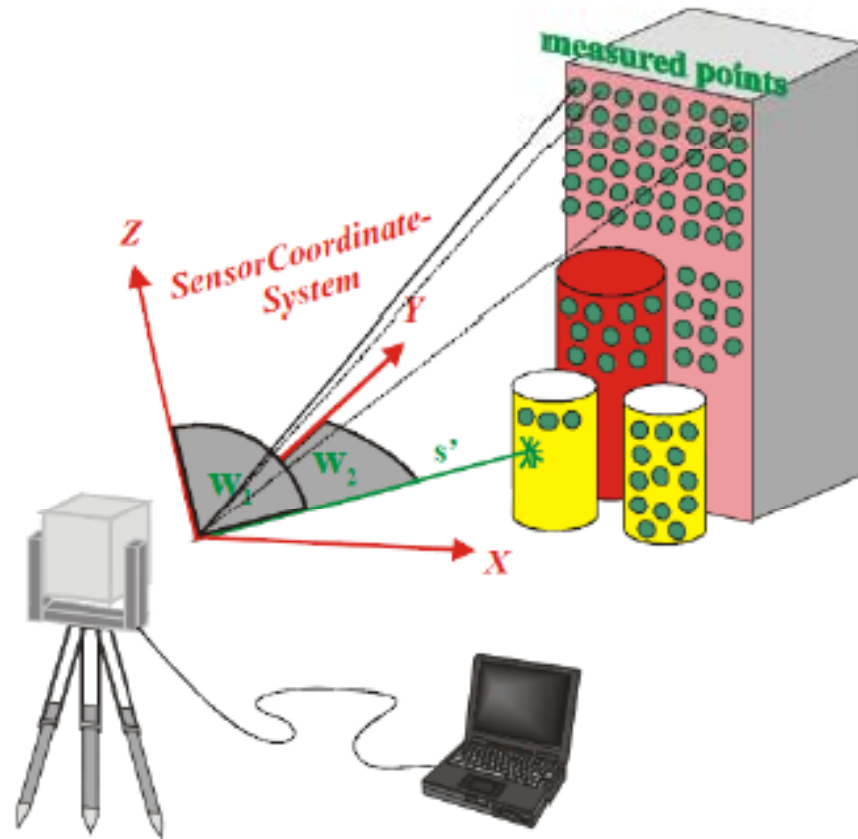
- Captures 3D position data of any point
- Dense data acquisition
- Non-contact → No need for instrumentation of sensors on structure
- Ability to capture data for structures that are not easy to access
- Reasonably accurate for many applications
- Versatile
- Efficient
- Easy to use



# **How laser scanning works ?**

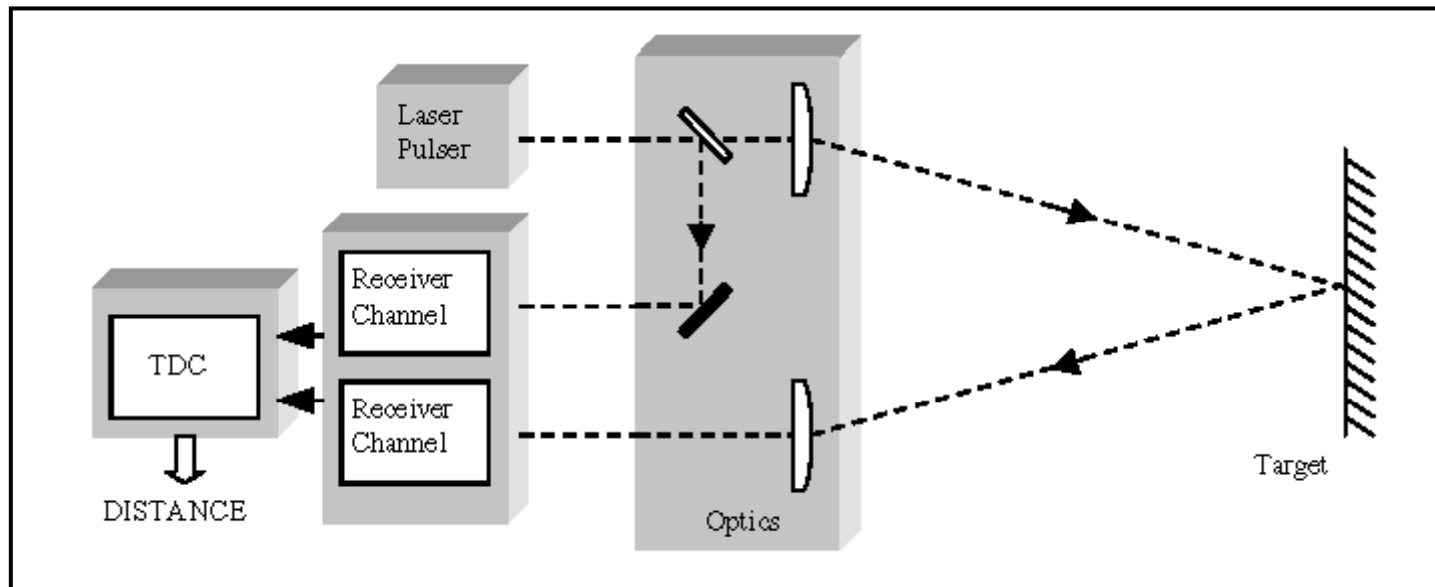


# How Laser Scanning Works



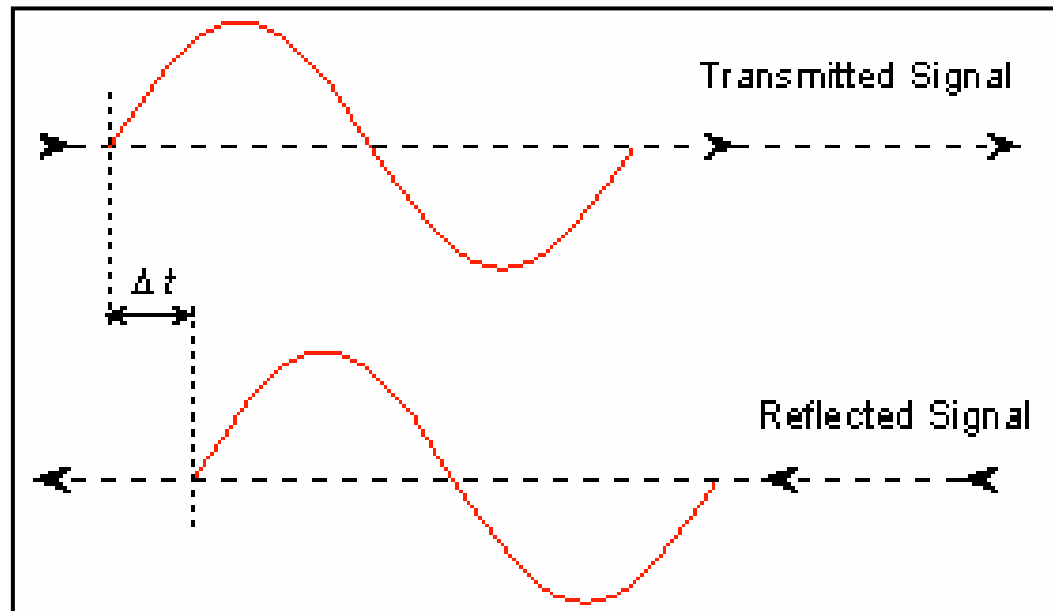
## How Laser Scanning Works

- Time of Flight
  - Measures time it takes a laser pulse to travel to target and back to determine distance



## How Laser Scanning Works

- Phase Shift
  - Measures change in phase of multiple sinusoidal laser pulses to determine time and distance





# Faro Focus 3D







## Faro Focus 3D

- **The new Sensor features include Compass, Height Sensor and Dual Axis Compensator: more**
- **New WLAN (WiFi):** WLAN remote control permits you to start, stop, view or download scans at a distance.

**Intuitive touchscreen display:** Control all scanner functions with a touch interface for unparalleled ease of use and control

- **Stand-alone solution:** Ultraportable design allows for operation without external devices
- **Small and compact:** With a size of only 24 x 20 x 10cm<sup>3</sup> and a weight of just 5.0kg, the Focus<sup>3D</sup> is the smallest 3D scanner ever built
- **Integrated colour camera:** Photorealistic 3D c**The new Sensor features include Compass, Height Sensor and Dual Axis Compensator: more**
- **New WLAN (WiFi):** WLAN remote control permits you to start, stop, view or download scans at a distance.



## Faro Focus 3D

- New FARO Focus<sup>3D</sup> features include:
- **Compass**  
The new electronic compass attaches orientation data to each scan. This is a big contribution to a successful auto-registration.
- **Height Sensor (Altimeter)**  
Each scan now receives height information. For example this will be useful scanning different floor levels in a building which then can be differentiated via the height data.
- **Dual Axis Compensator**  
All scans receive the level information which provides to be very helpful in minimizing the number of targets.
- **WLAN (WiFi)**  
WLAN remote control permits you to start, stop, view or download scans at a distance.



## Faro Focus 3D

Architecture and civil engineering  
Process industry and digital factory  
Inspection and reverse engineering  
Heritage  
Forensics and accident scenes

<http://www.faro.com/focus/uk/videos>

# Leica ScanStation C-10



## System Performance

### Accuracy of single measurement

Position*	6 mm
Distance*	4 mm
Angle (horizontal/vertical)	60 $\mu$ rad / 60 $\mu$ rad (12" / 12")

<b>Modeled surface precision**/noise</b>	2 mm
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<b>Target acquisition***</b>	2 mm std. deviation
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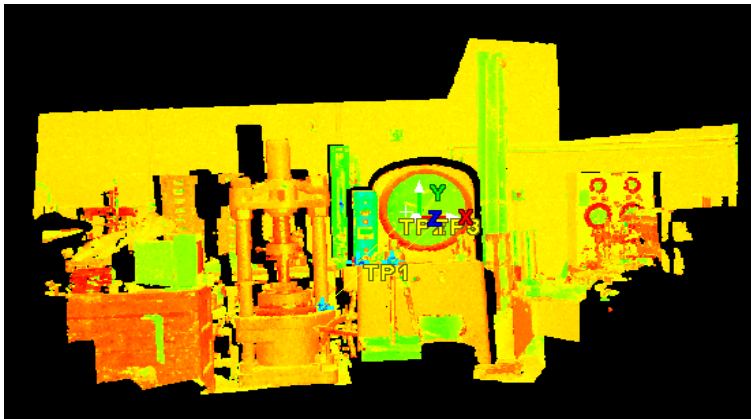
<b>Dual-axis compensator</b>	Selectable on/off, resolution 1", dynamic range +/- 5', accuracy 1.5"
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## Laser Scanning System

<b>Type</b>	Pulsed; proprietary microchip
<b>Color</b>	Green, wavelength = 532 nm visible
<b>Laser Class</b>	3R (IEC 60825-1)
<b>Range</b>	300 m @ 90%; 134 m @ 18% albedo (minimum range 0.1 m)
<b>Scan rate</b>	Up to 50,000 points/sec, maximum instantaneous rate
<b>Scan resolution</b>	
Spot size	From 0 – 50 m: 4.5 mm (FWHH-based); 7 mm (Gaussian-based)
Point spacing	Fully selectable horizontal and vertical; < 1 mm minimum spacing, through full range; single point dwell capacity
<b>Field-of-View</b>	
Horizontal	360° (maximum)
Vertical	270° (maximum)
Aiming/Sighting	Parallax-free, integrated zoom video
<b>Scanning Optics</b>	Vertically rotating mirror on horizontally rotating base; Smart X-Mirror™ automatically spins or oscillates for minimum scan time
<b>Data storage capacity</b>	80 GB onboard solid-state drive (SSD) or external USB device

## Leica HDS 2500

- Time of flight
- Accuracy:  $\pm 6$  mm
- Range: Up to 100 m
- Scan rate: 1000 pts/s
- Field of View:  $40^\circ$  by  $40^\circ$
- Software: Cyclone



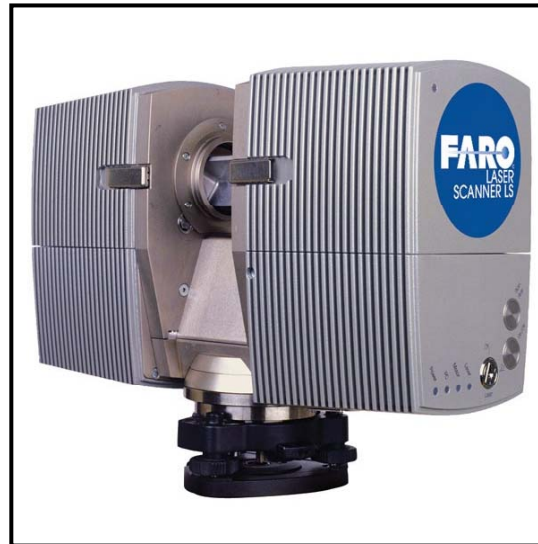
## Operation

- Set up equipment
  - Scanner, computer
- Position targets as needed
- Scan
- Use software for post-processing
  - Visualization
  - Stitching/Registration
  - Meshing



## Other Scanning Systems

- Leica
- Faro
- Riegl
- Optech
- Trimble
- Price range:
  - Euro 25,000 - Euro150,000



Faro LS 880



Riegl LMS Z420



## V-Line of 2D- and 3D laser scanners

### Airborne Scanning

**RIEGL VQ-480**



- Scan Range:** ● 60 deg
- Laser Clock:** ● 50 kHz -300 kHz
- Max. Range:** ● 800 m (50kHz,20%)  
450 m (300kHz,20%)

### Mobile Scanning

**RIEGL VQ-180 RIEGL VQ-250**



- 100 deg
- 200 kHz
- 500 m (20%)
- 360 deg
- 50 kHz -300 kHz
- 300 m (80%)

### Terrestrial Scanning

**RIEGL VZ-400**



- 100 x 360 deg
- 100/300 kHz
- 500 m (80%)

V-Line

[www.riegl.com](http://www.riegl.com)





# inherited and innovative new features

LMS Z-Series



- wide field of view
- robust & reliable
- harsh environments
- near range photogrammetry & laser scanning

LMS-Q560



- echo signal digitization
- digital signal processing
- off-line full waveform processing

LPM-321



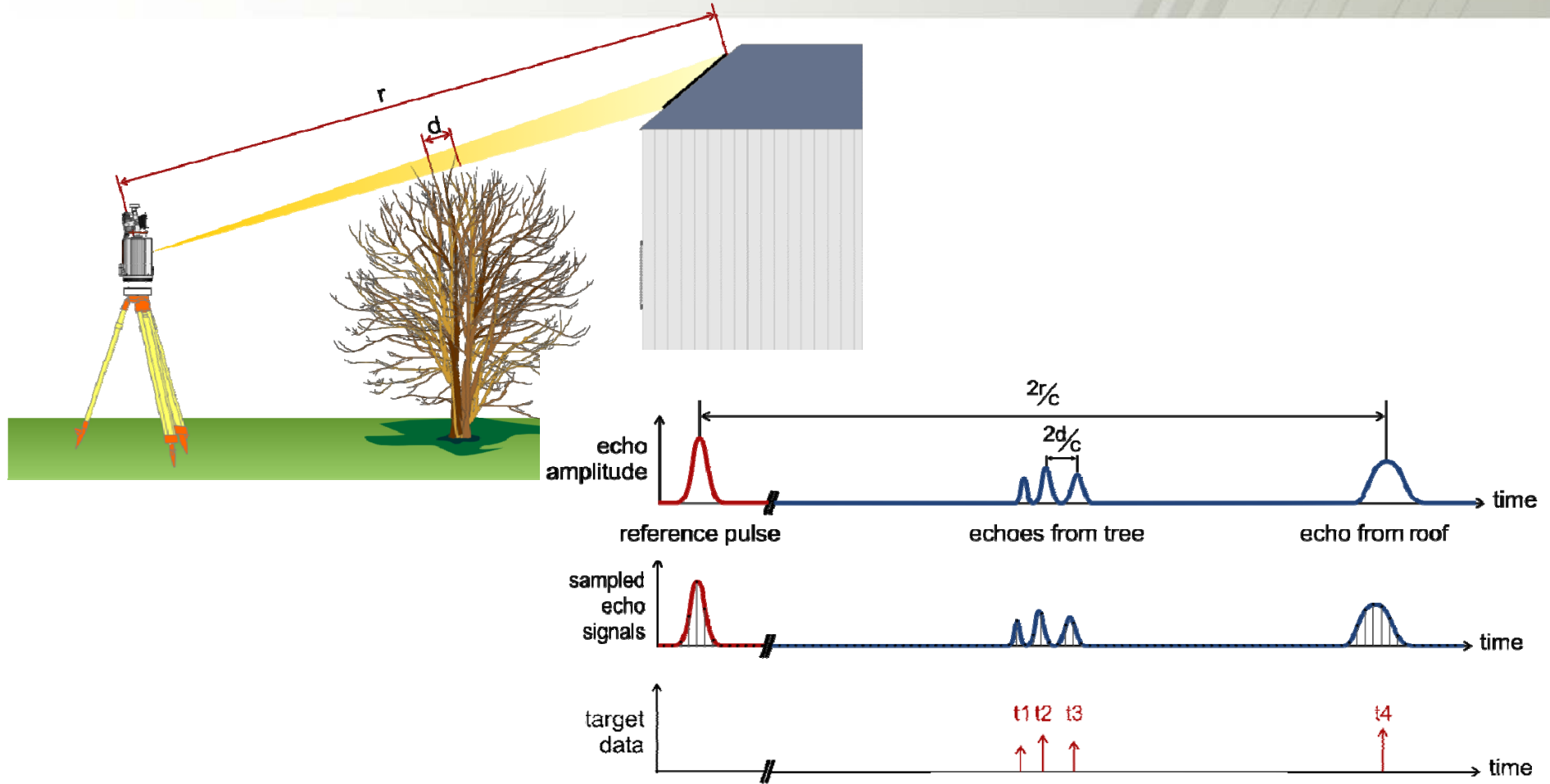
- echo digitization
- online waveform analysis



## New Features:

- 2-in-1 3D scanner: high speed / long range
- high-speed online waveform processing
- online multi-target point cloud (True3D)
- accurate echo waveform assessment
- calibrated amplitude
- display and keypad
- attachable battery
- internal data storage
- integrated WLAN / LAN
- tilt sensor
- laser plummet

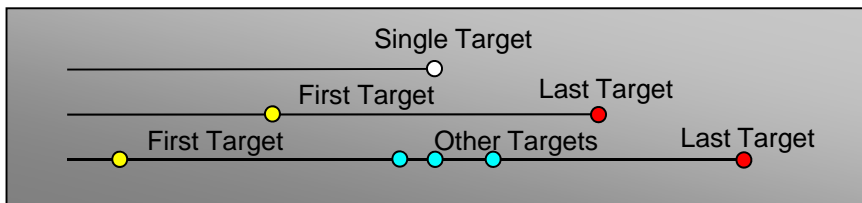
# echo digitization



echo digitization



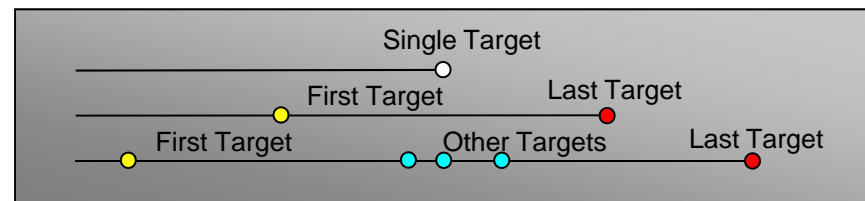
# multi-target capability





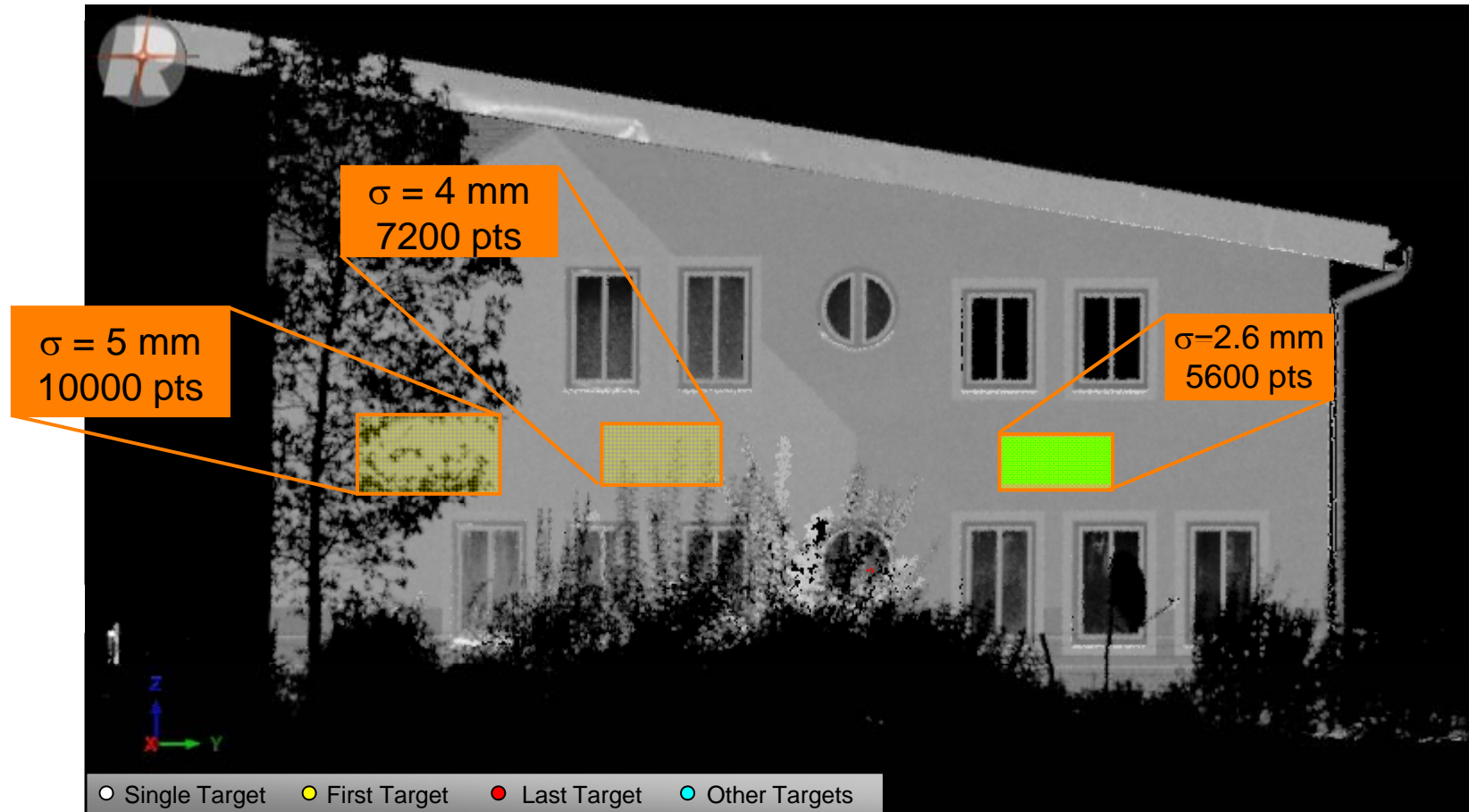
# multi-target capability

Example: car partly obscured by vegetation





# precision and accuracy



## calibrated amplitude

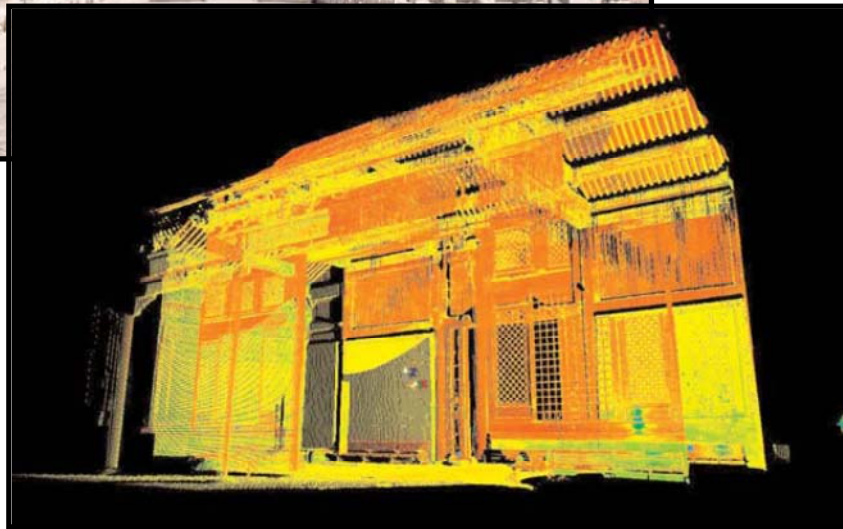
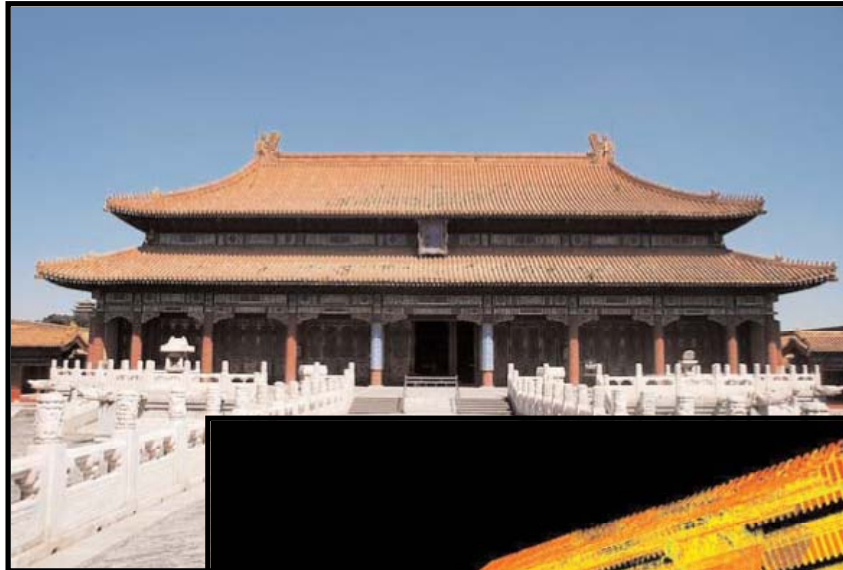
- Amplitude of each target reading is ratio to optical echo amplitude at detection threshold, in units of dB.  
E.g.,  $a = 23 \text{ dB} \rightarrow$  optical amplitude equals 200 x amplitude at detection threshold
- Instrument provides lookup table with mean amplitude of return from target with 100% diffuse reflectivity over range
- $\rightarrow$  by applying lookup value, amplitude reading can easily be converted to diffuse reflectivity in dB.  
E.g.,  $-10 \text{ dB} \rightarrow$  amplitude corresponds to amplitude from 10% target at the same distance,  $+13 \text{ dB} \rightarrow$  retro-reflecting target giving 20 times the signal of a white diffuse target at the same distance
- equivalent conversion to laser radar cross section



# Applications



# Applications



## Historical Documentation



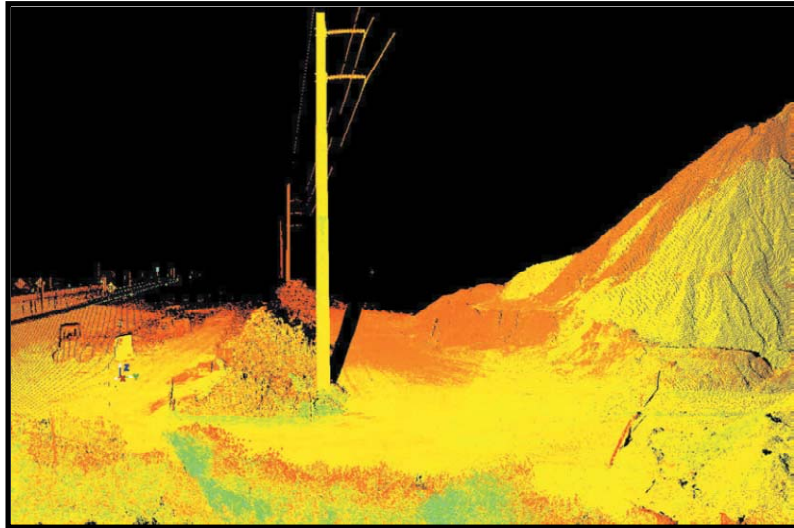
Images from [www.leica-geosystems.com](http://www.leica-geosystems.com)

Palace Museum in the “Forbidden City” in Beijing



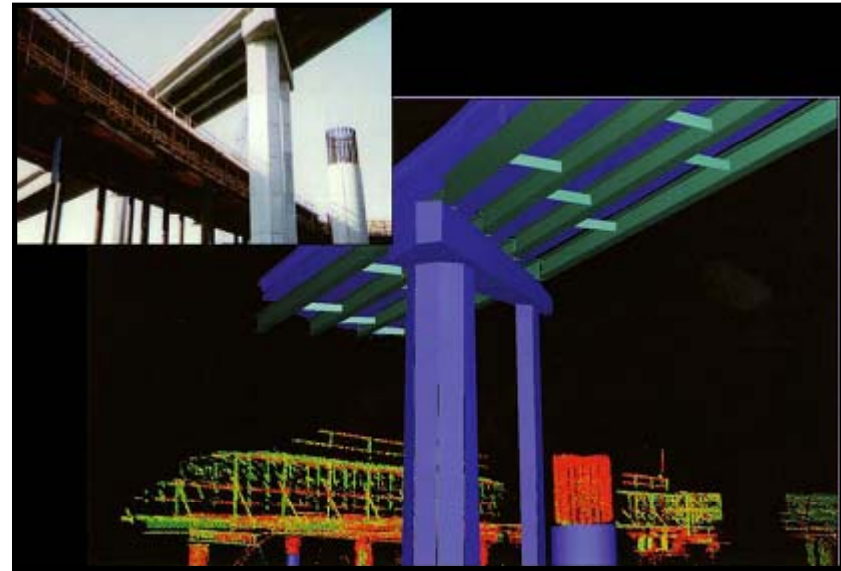


# Applications



← Survey

Construction  
Inspection →

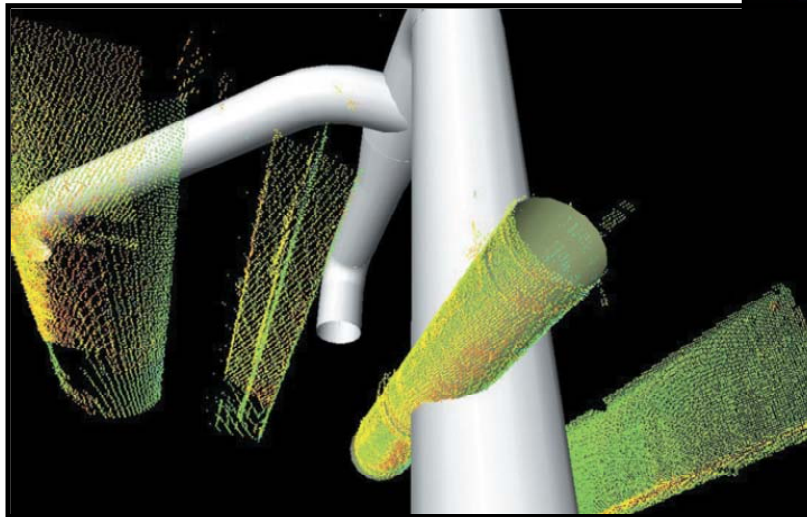
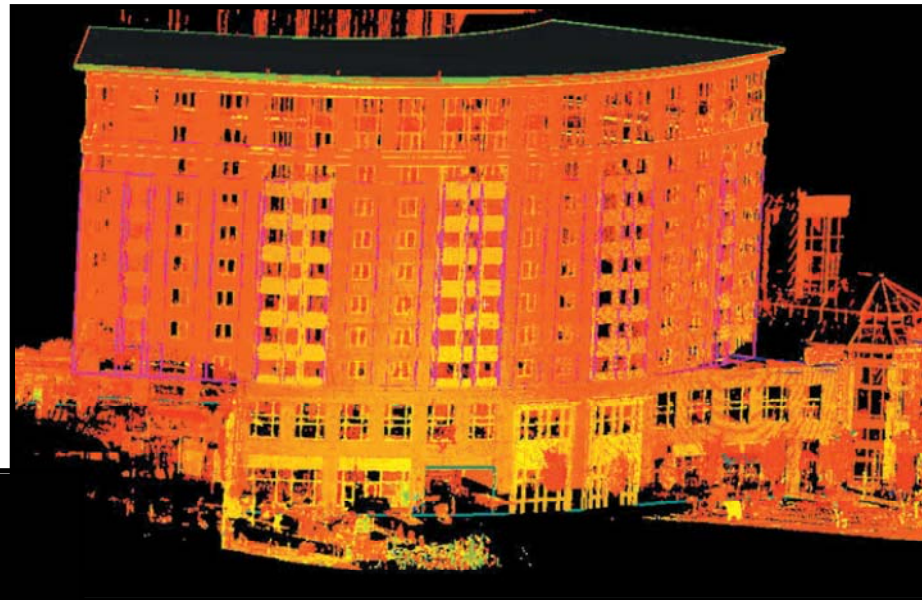


Images from [www.leica-geosystems.com](http://www.leica-geosystems.com)



# Applications

As-built  
documentation →

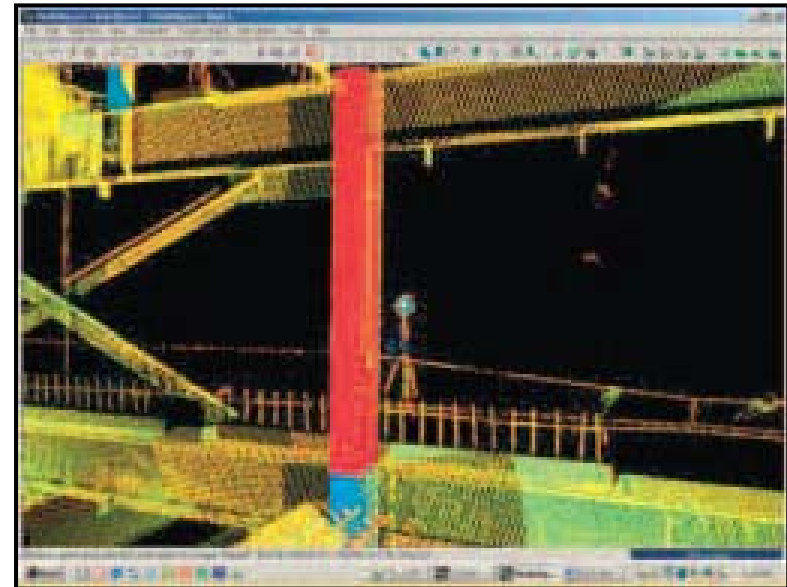
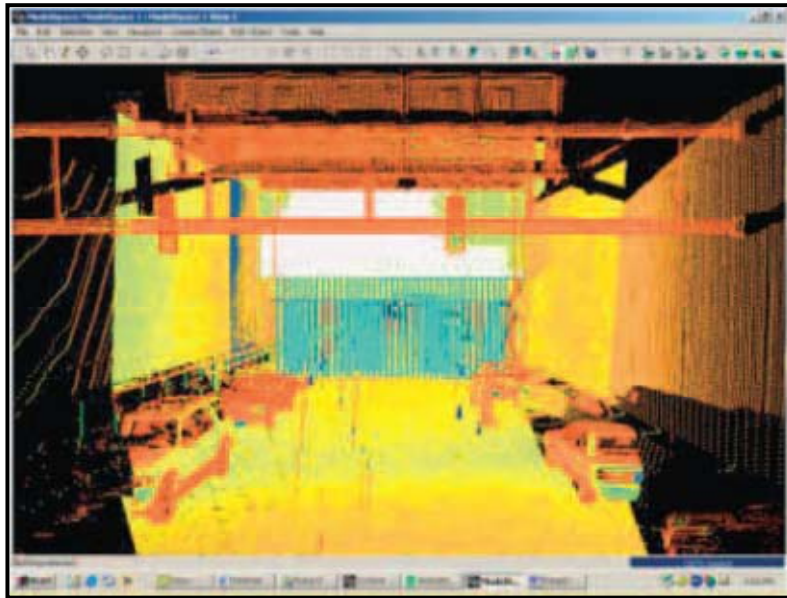


← Retrofit



# Applications

- Survey
- Closeout drawings





# Applications

## Forensics

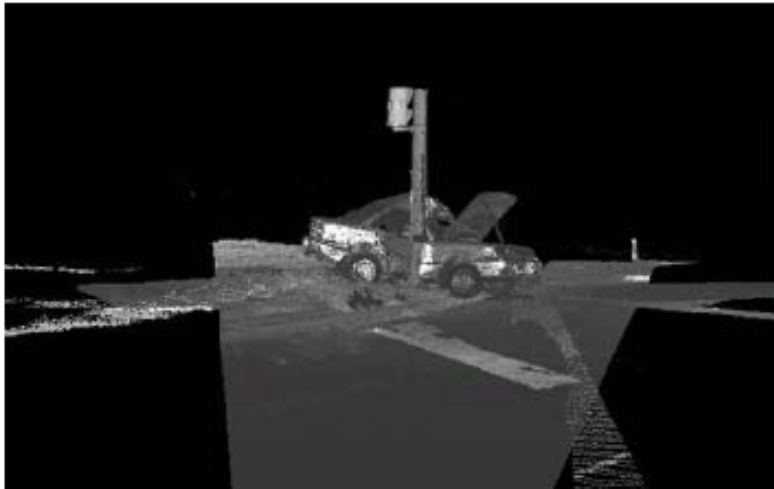
- I-35 W bridge in Minnesota
- Riegl LMS Z420



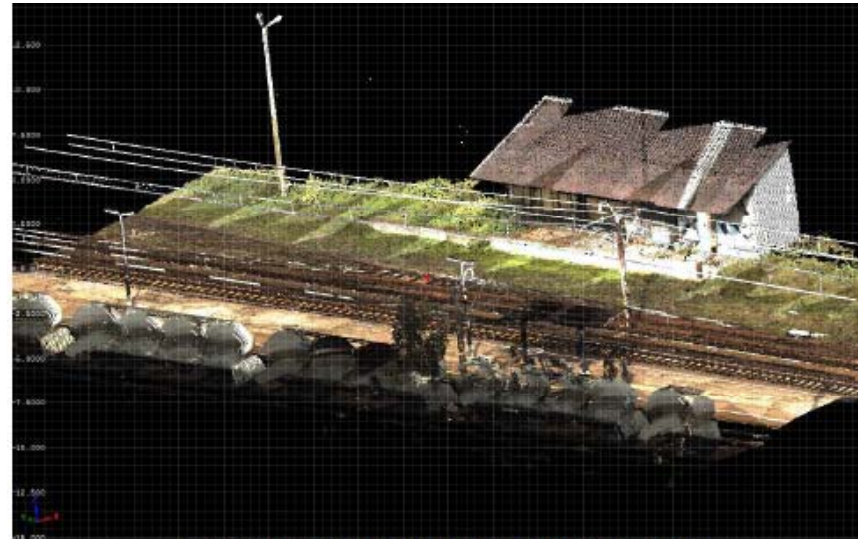


# Applications

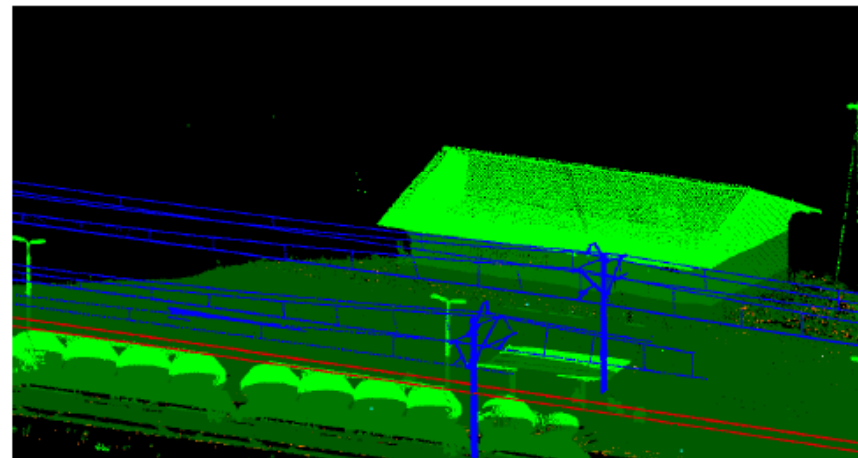
## Crash documentation



## PLK Project



Rys.3.31 Peron w Słomnikach na pokolorowanej chmurze punktów.





# Architecture



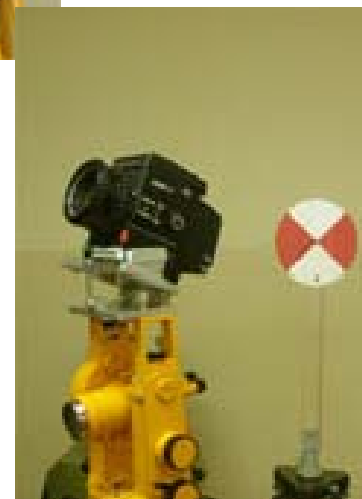
## *Laser scanning and photogrammetry data integration – an example*

Purpose :

- 3D Wizualization
- Documentation



# Photo-theo





# ROLLEIMETRIC 6008 AF



Matrix:

4076 pikseli (36,684 mm)

4080 pikseli (36,72 mm)

Resolution:

9  $\mu\text{m}$  (16,6 megapikseli).

Lens:

Planar 2.8/80 mm

Digital - Phase One model P20



*Wiatrak z Grzmucina*



# Project - example

**Tachimeter  
Leica TCR 407 power**



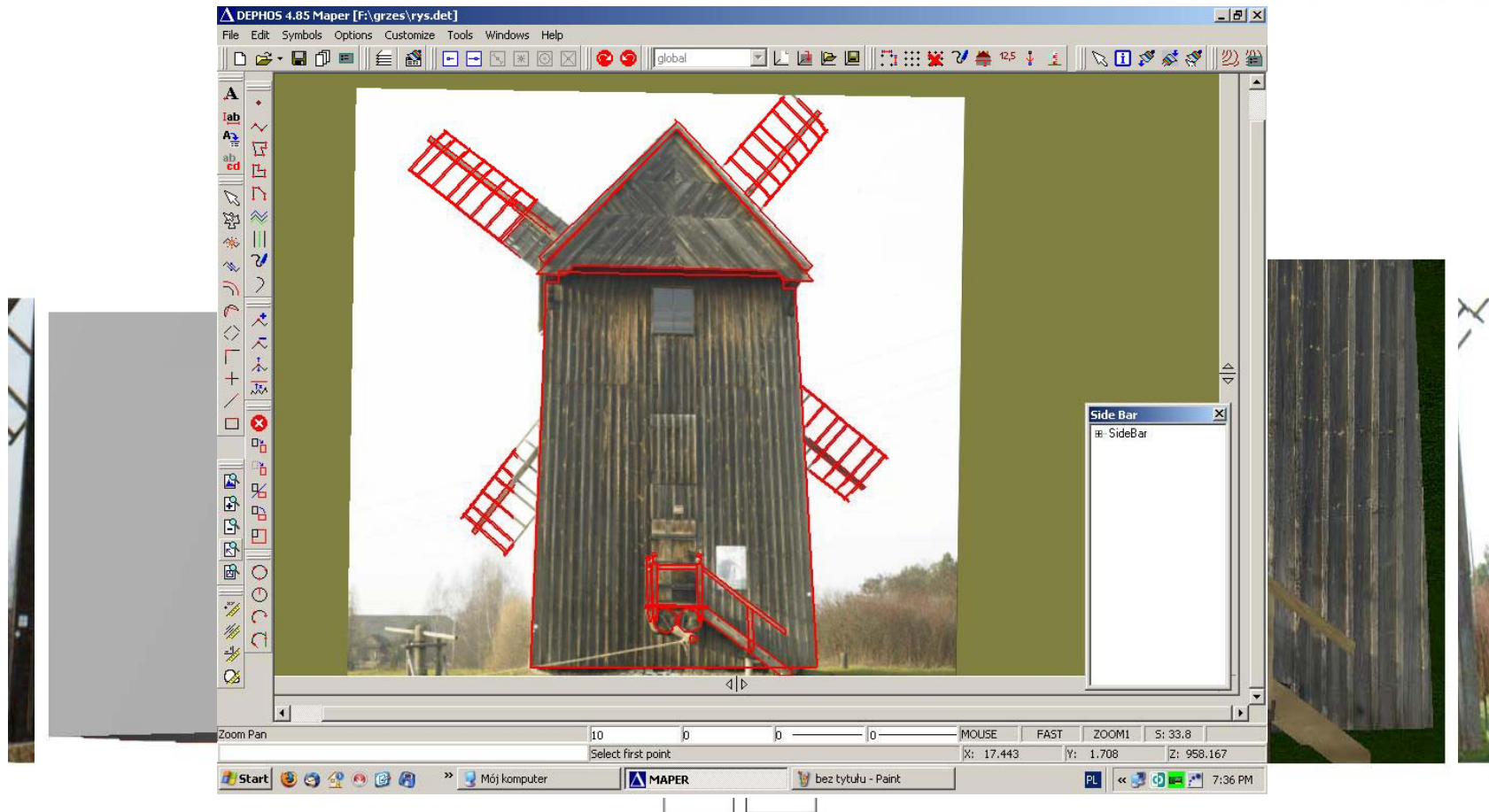
**Scanner  
Imager 5006**



# Project - example

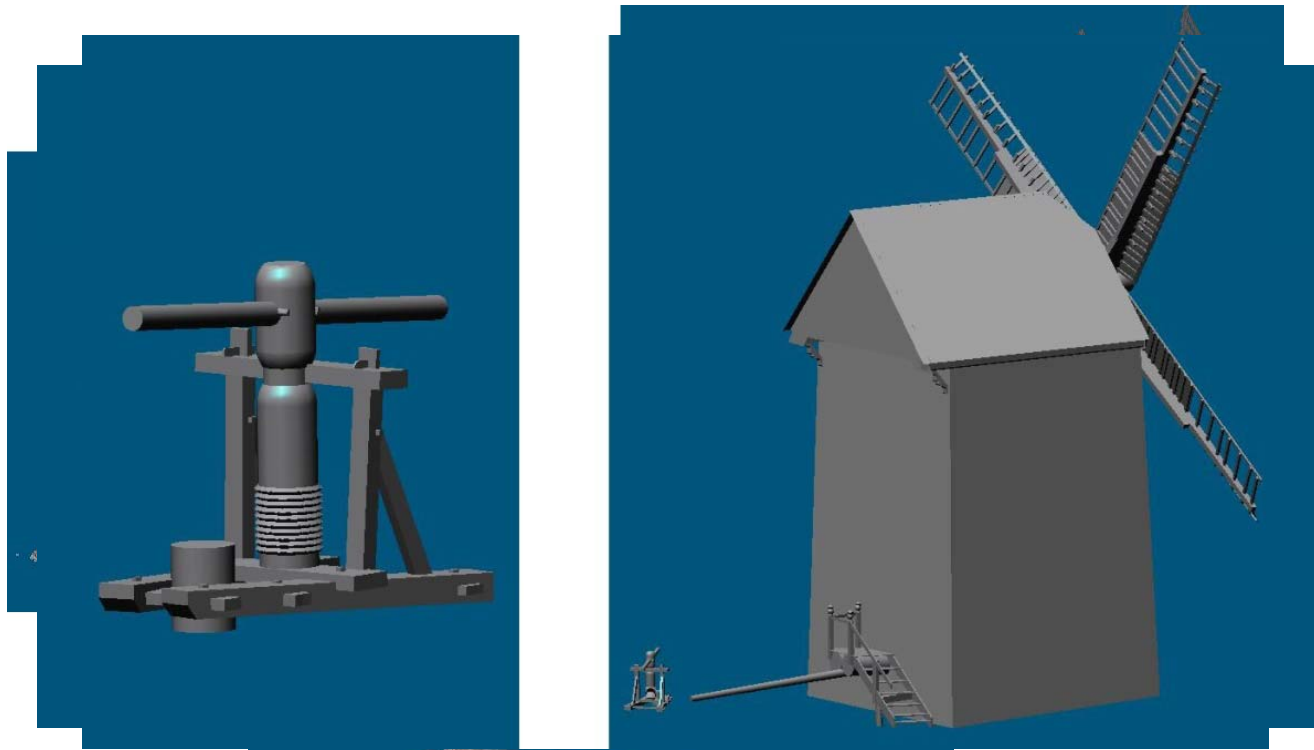


# Project - example





# Project - example





# Project - example







**Thank you for your attention !**