



fsm 2007  
Houston  
Texas



**RIEGL**  
LASER MEASUREMENT SYSTEMS



- 2 Operators
- *RIEGL* 3D Laser Scanner
- NIKON D200 & CANON G6
- Google Earth for Registration
- RiSCAN PRO & Phidias



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Scan Position 1



Scan Position 2





Scan Position 3



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Scan Position 4



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Scan Position 5



Scan Position 6



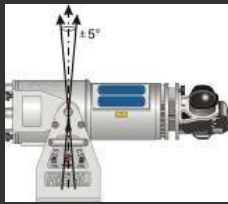


Scan Position 7



Scan Position 9

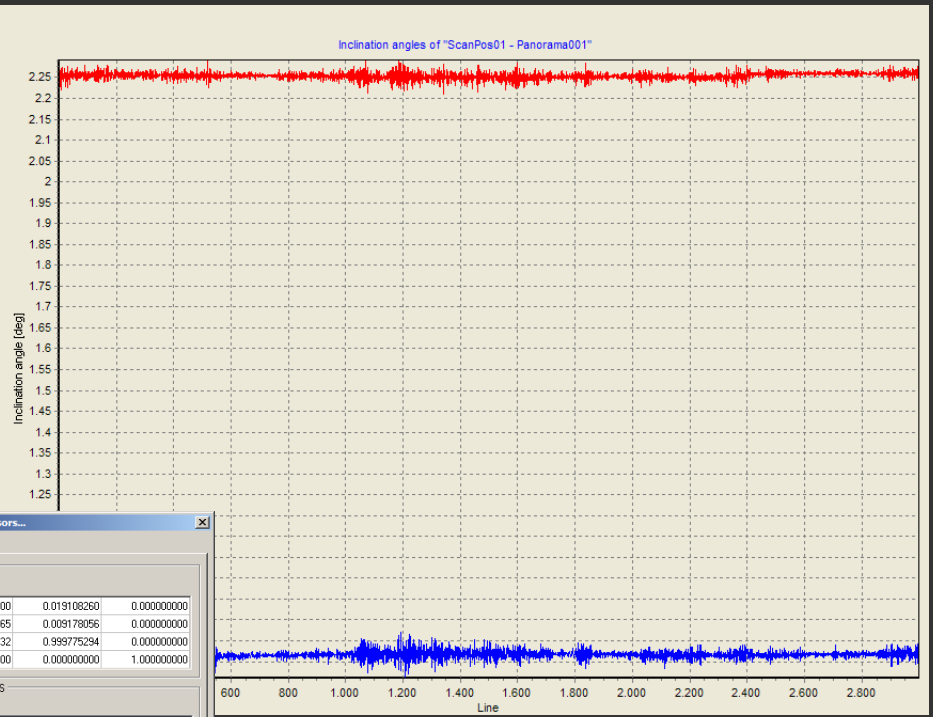




Scanner orientation  
stand up  
Total line count: 3000

Rotation around Y axis  
 Visible  
Min: 0.810  
Max: 0.920  
Delta: 0.110  
Mean: 0.866  
StdDev: 0.011

Rotation around X axis  
 Visible  
Min: 2.211  
Max: 2.292  
Delta: 0.081  
Mean: 2.254  
StdDev: 0.009



Calculate SOP via inclination sensors...

Calculation

MATRIX:

SOP:				
0.939817421	0.000000000	0.019108260	0.000000000	0.000000000
-0.000175409	0.999957865	0.009178056	0.000000000	0.000000000
-0.019107455	-0.009179732	0.999775294	0.000000000	0.000000000
0.000000000	0.000000000	0.000000000	1.000000000	0.000000000

CALCULATION SETTINGS

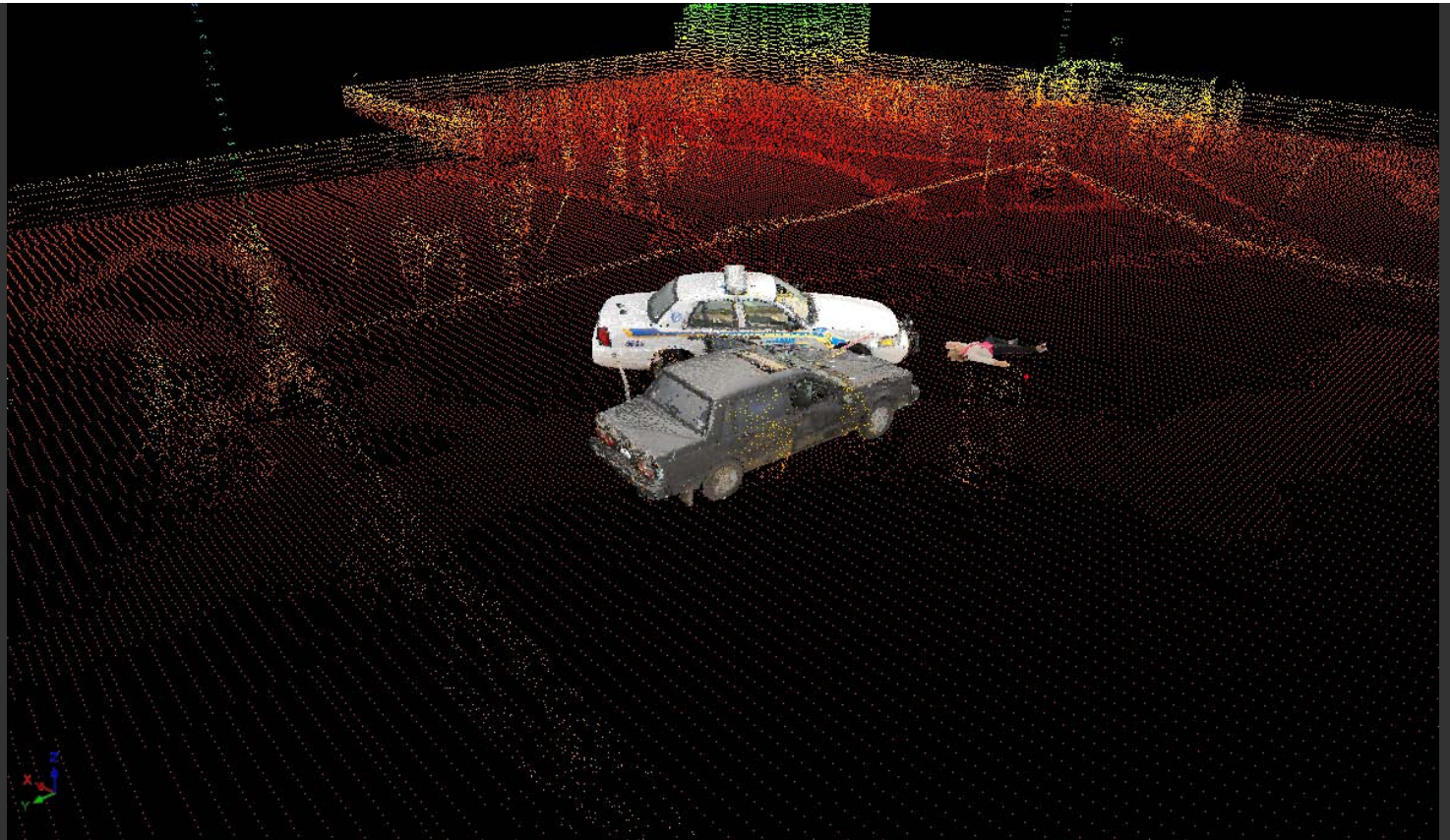
Scans:  
BeamWidening\_ScanPos01 - Panorama001

Calculate

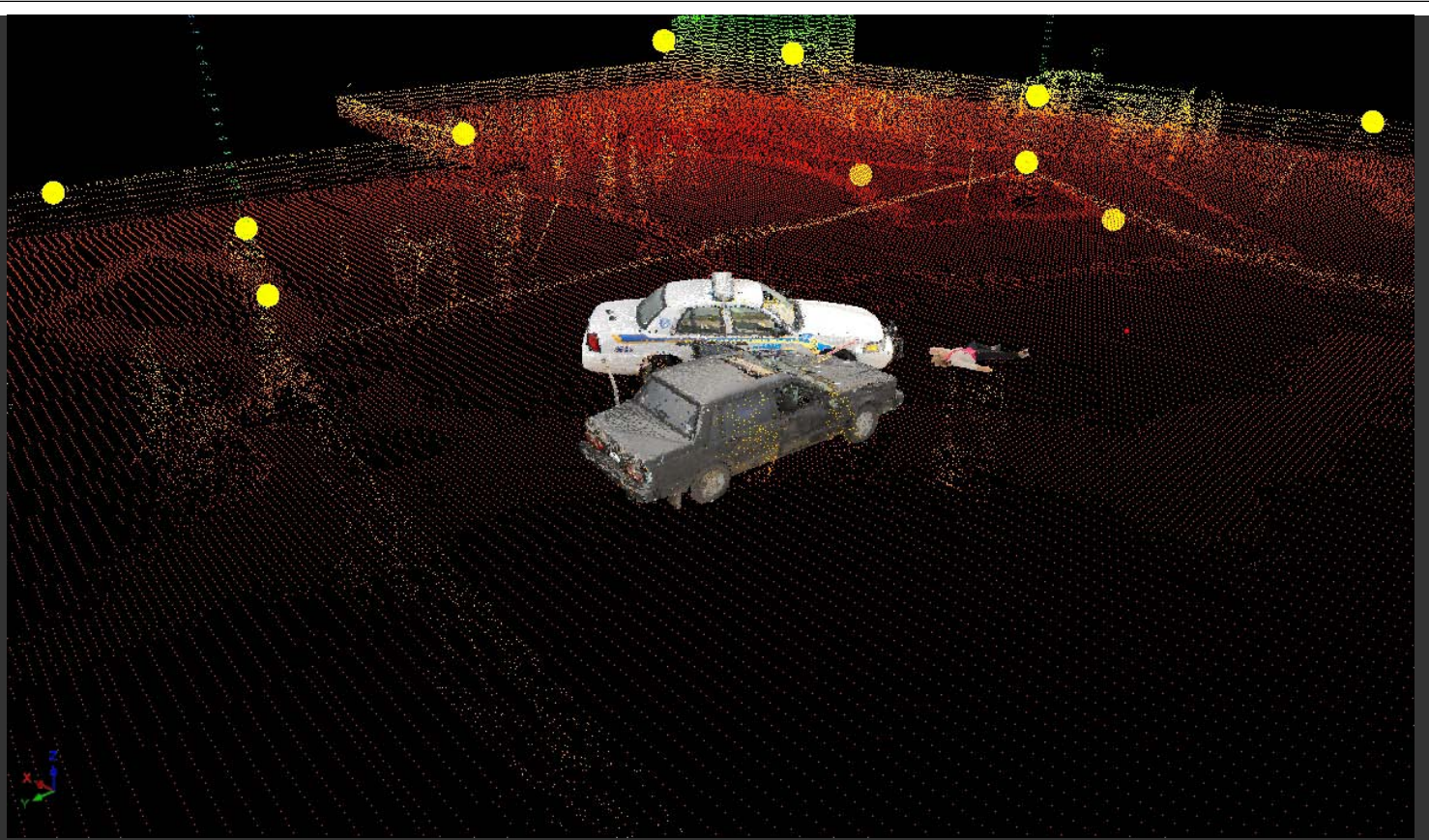
OK Cancel Help



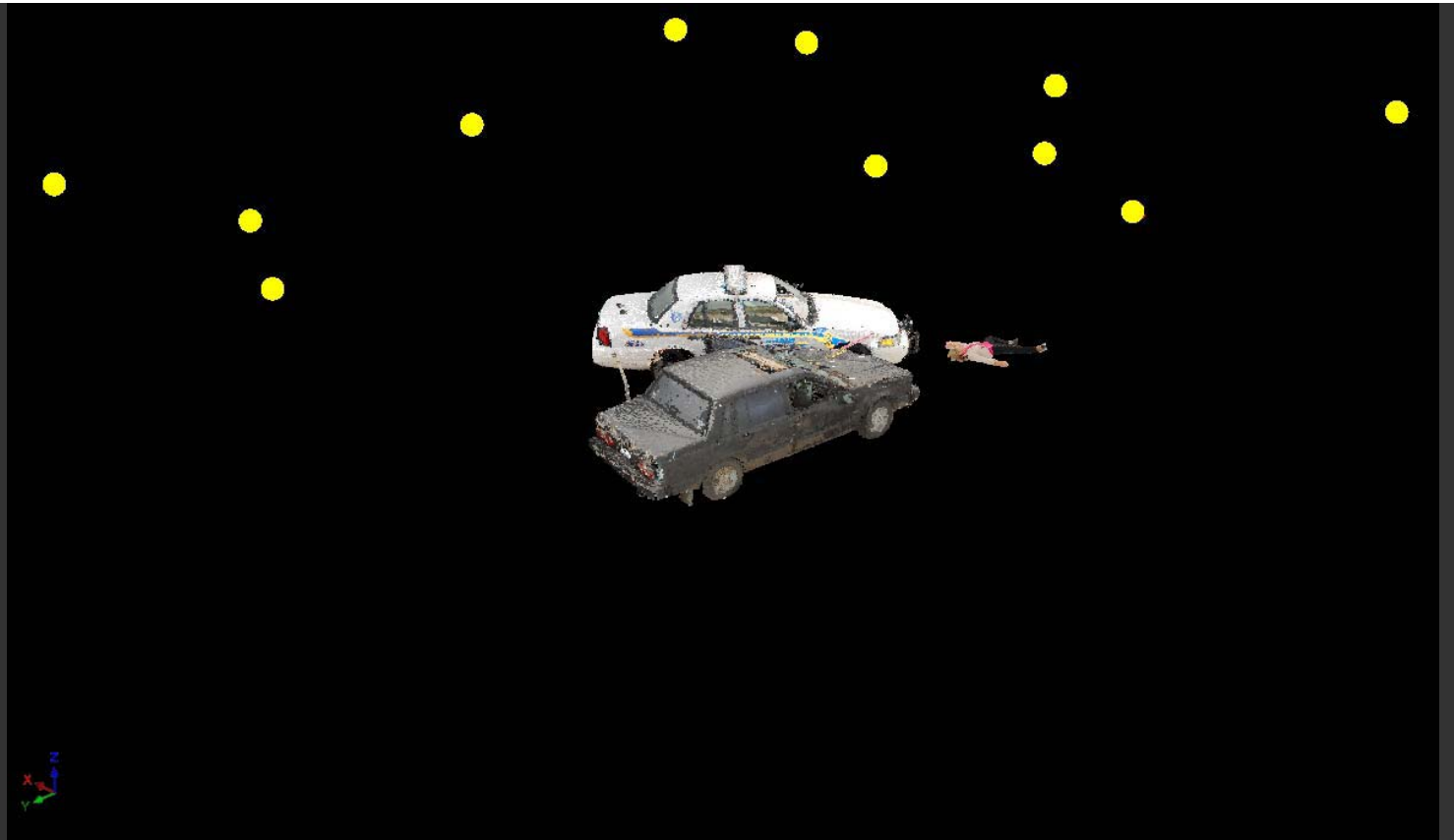
# Registration - Inclination Sensor



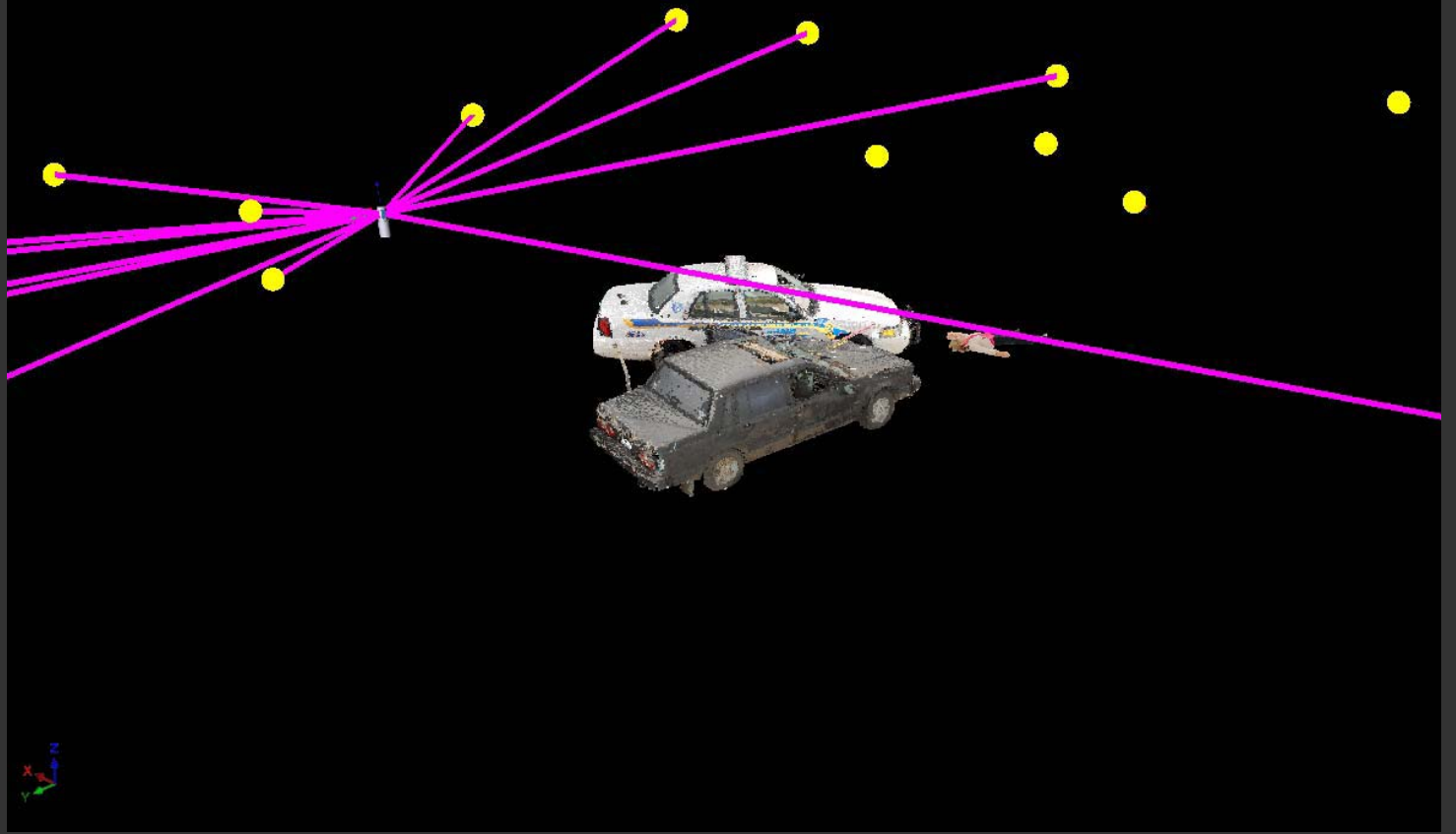
# Registration



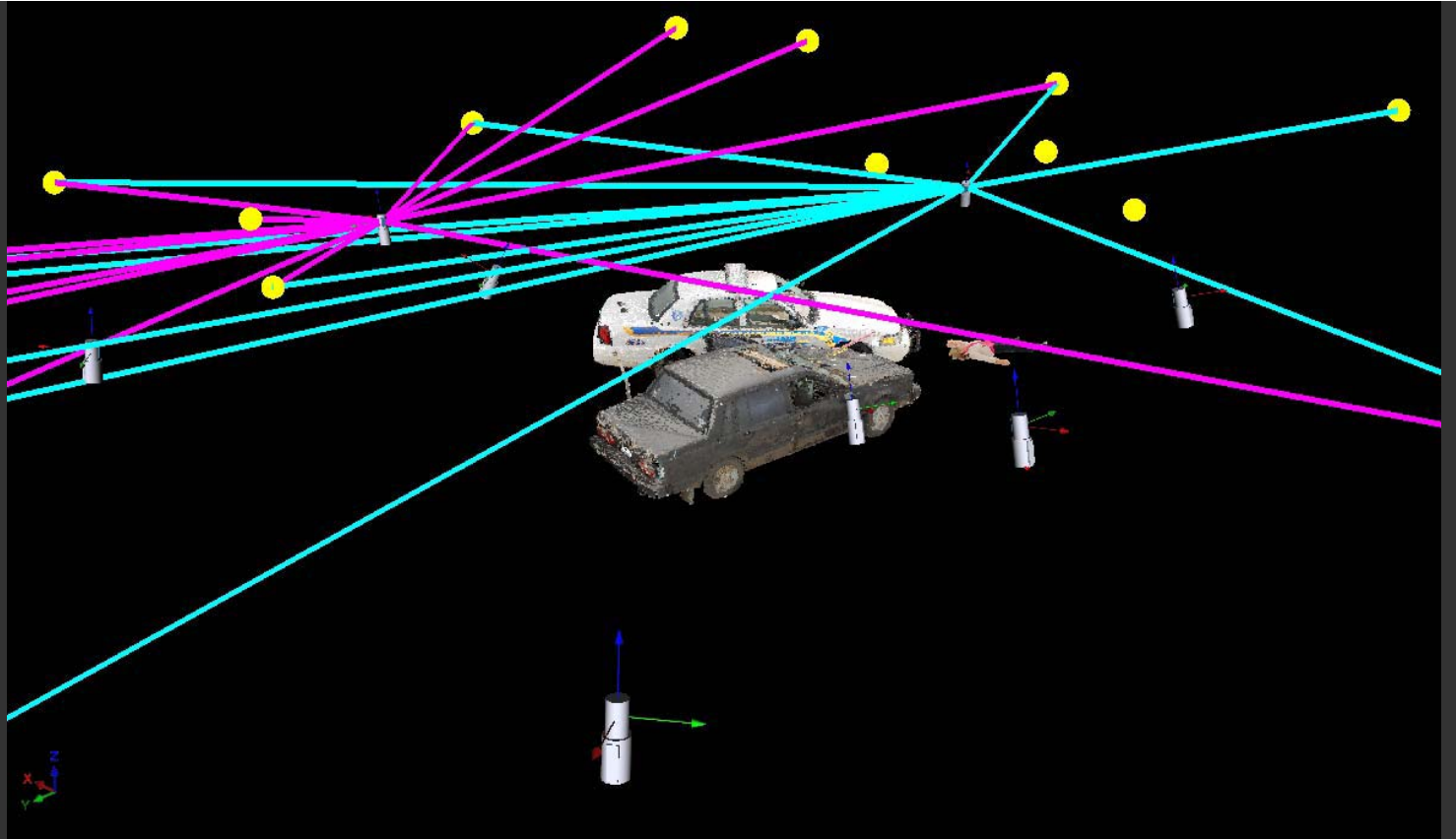
Registration



Registration

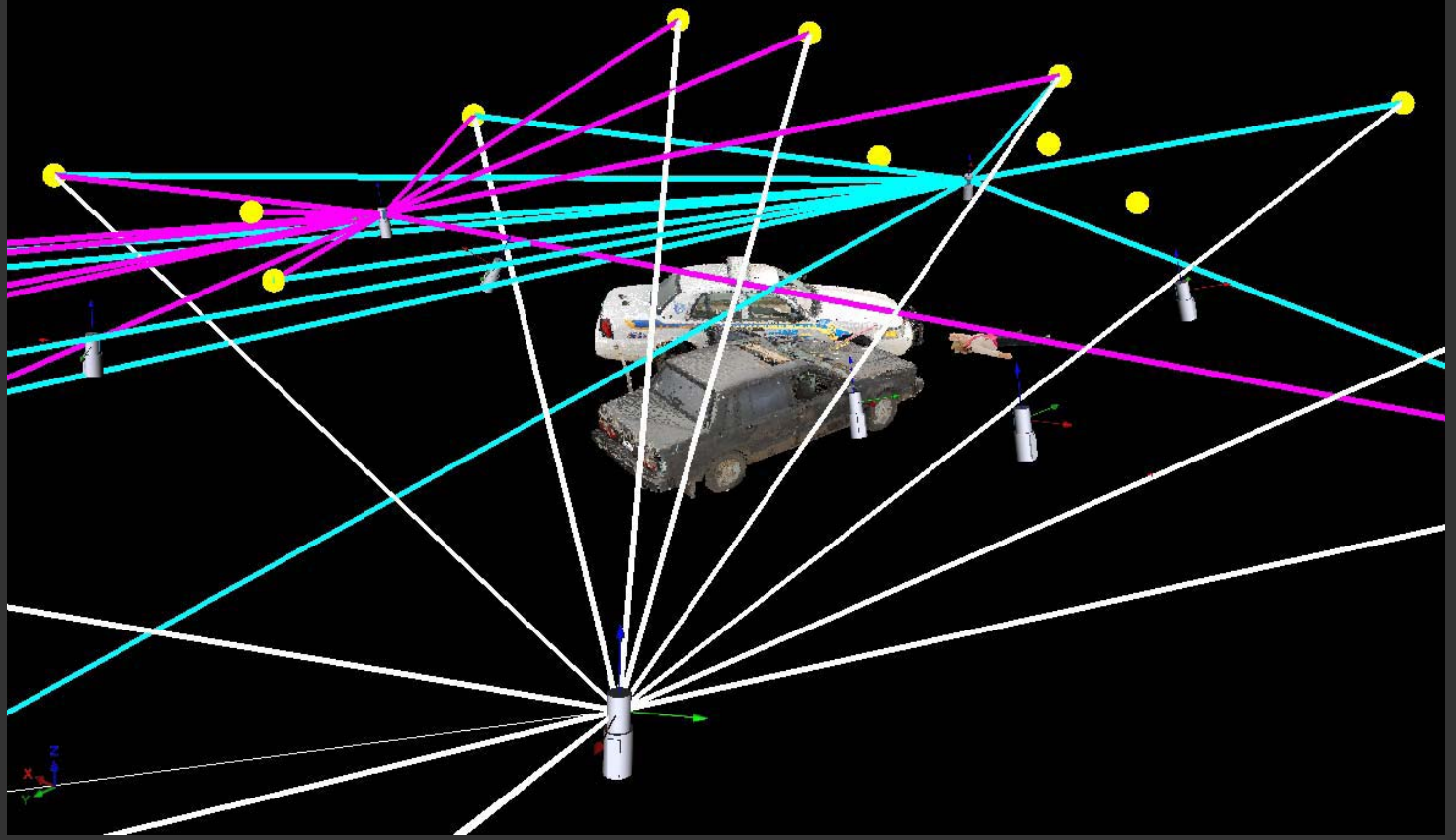


Registration



Registration





## Registration

Project: 2007\_03\_Houston

Error (StdDev) [m]: 0.0036m

Number of pointpairs used for calculation:

Tiepoints: 274

Name	delta X	delta Y	delta Z	delta Roll	delta Pitch	delta Yaw	#	Remarks
ScanPos01	0.000	0.000	0.000	0.000	0.000	0.000	204	Locked
ScanPos02	0.000	0.000	0.001	0.003	0.004	0.002	162	
ScanPos03	0.000	0.000	0.000	0.001	0.002	0.002	201	
ScanPos04	0.001	-0.001	0.001	-0.002	0.001	0.003	180	
ScanPos05	0.000	-0.001	0.002	0.001	-0.004	0.002	189	
ScanPos06	0.000	0.000	0.001	0.001	0.000	0.001	165	
ScanPos07 Z420	-0.001	-0.001	0.000	0.000	0.000	0.002	165	
ScanPos08 Z420	-0.001	-0.001	0.001	-0.004	-0.002	0.003	96	
ScanPos09	0.001	-0.001	0.000	0.002	0.000	0.002	165	
ScanPos10	0.002	0.002	0.006	-0.002	-0.004	0.003	69	
ScanPos11	-0.001	-0.004	0.020	0.012	-0.007	-0.003	48	



## Registration Accuracy

- Time for Data Acquisition: 4h
- Time for Visualization (RiSCAN PRO): 8h
- Time for Postprocessing (Phidias): 10h



## Registration Accuracy



## Scan Position 1-9

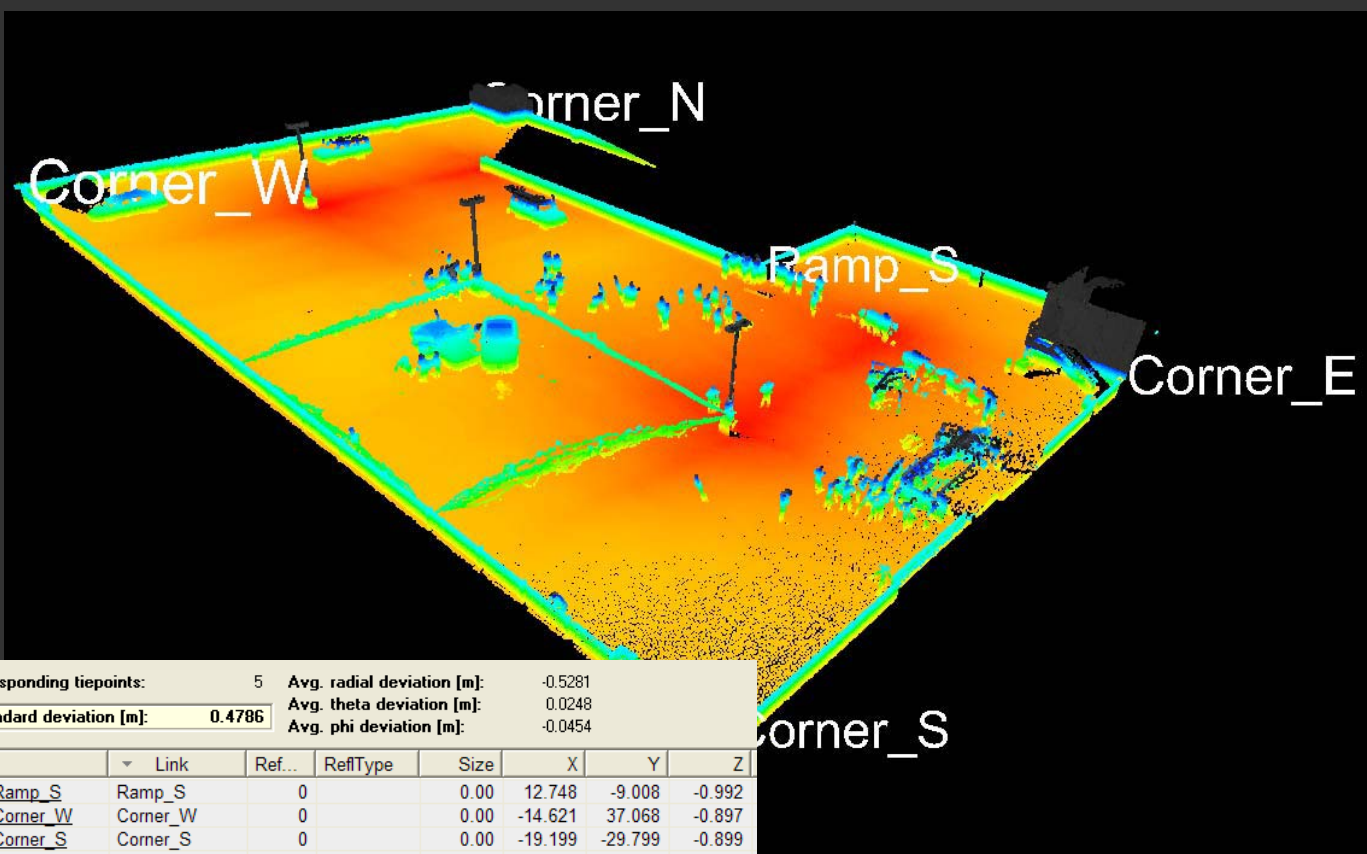




Corner_N	266.11	269.00	41.77
Corner_E	309.59	216.19	41.77
Corner_S	284.76	191.92	41.77
Corner_W	237.12	240.66	41.77
Ramp_S	290.38	230.70	41.77



Registration by Google Earth

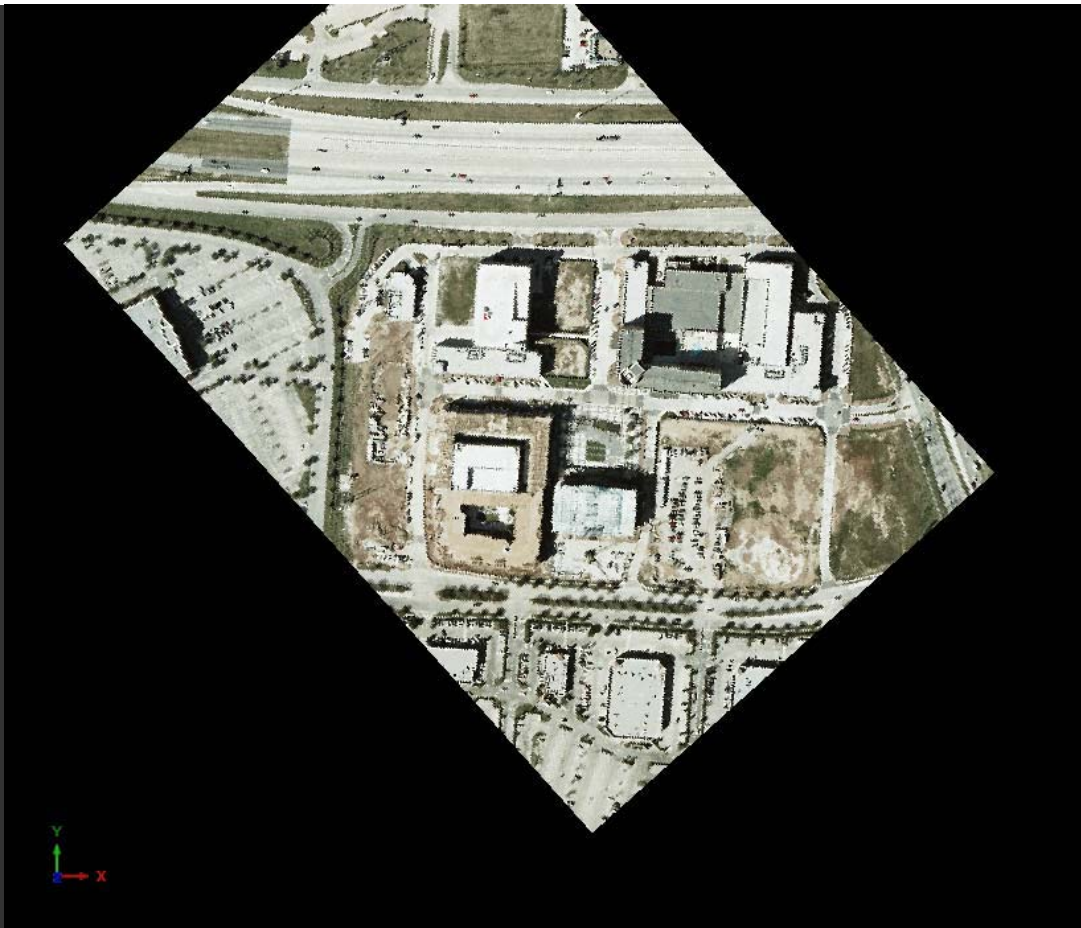


Corresponding tiepoints:	5	Avg. radial deviation [m]:	-0.5281
		Avg. theta deviation [m]:	0.0248
Standard deviation [m]:	0.4786	Avg. phi deviation [m]:	-0.0454

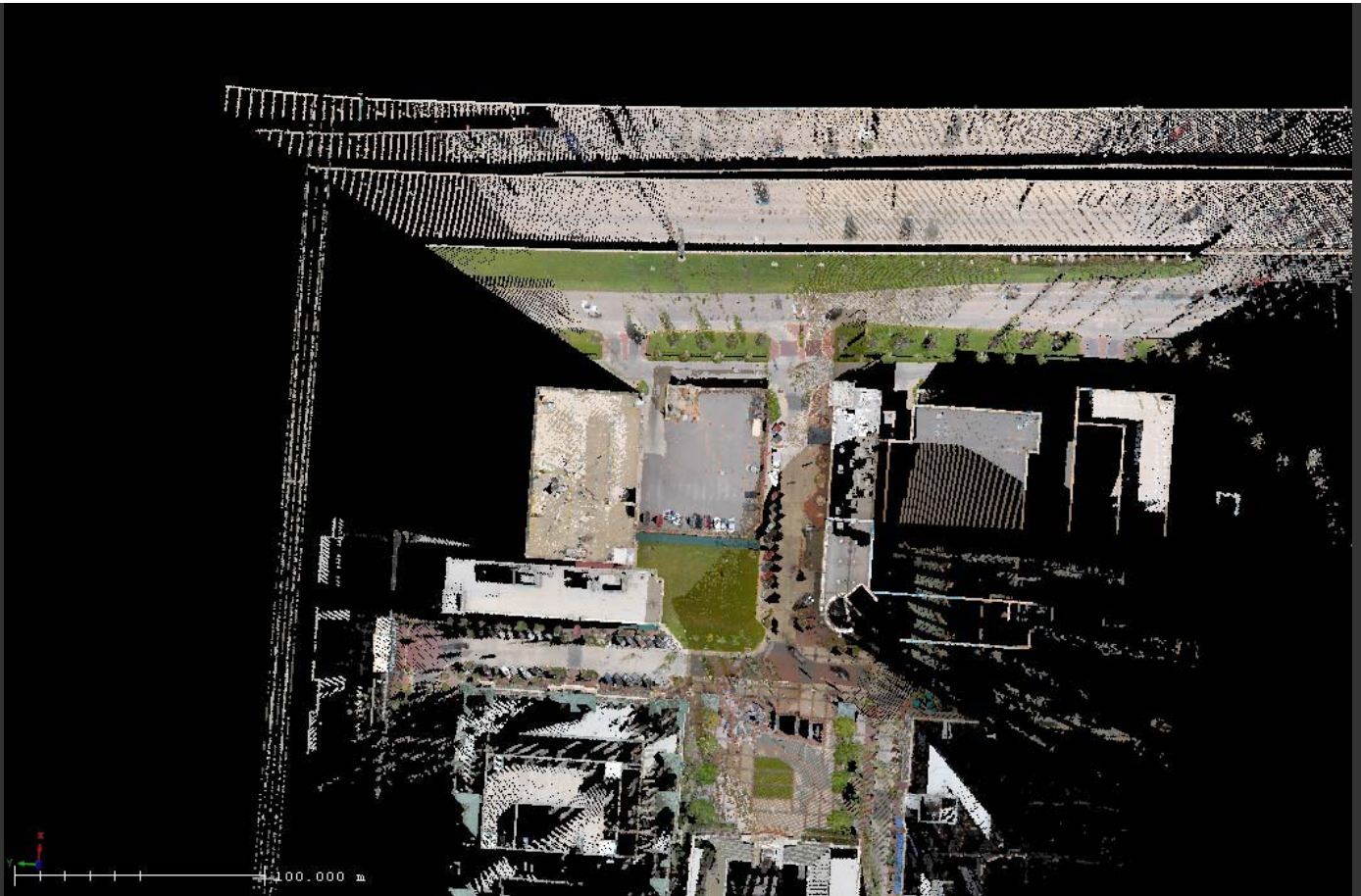
Name	Link	Ref...	RefType	Size	X	Y	Z
<input checked="" type="checkbox"/> Ramp_S	Ramp_S	0		0.00	12.748	-9.008	-0.992
<input checked="" type="checkbox"/> Corner_W	Corner_W	0		0.00	-14.621	37.068	-0.897
<input checked="" type="checkbox"/> Corner_S	Corner_S	0		0.00	-19.199	-29.799	-0.899
<input checked="" type="checkbox"/> Corner_N	Corner_N	0		0.00	24.720	34.569	-1.028
<input checked="" type="checkbox"/> Corner_E	Corner_E	0		0.00	14.831	-32.175	-0.995



Registration by Google Earth



Google with 3D Point Cloud



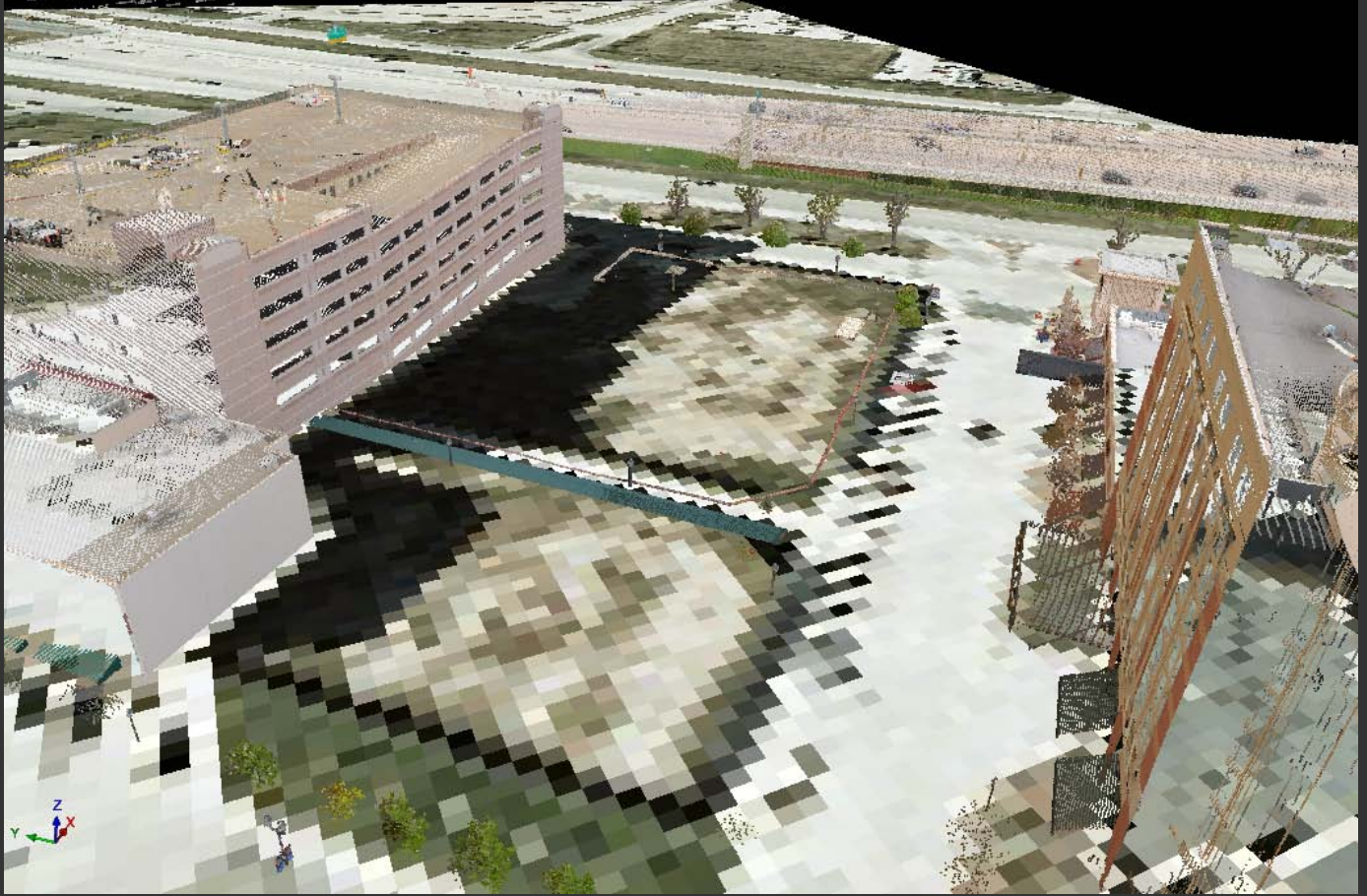
Google with 3D Point Cloud



Google with 3D Point Cloud



Google with 3D Point Cloud



Google with 3D Point Cloud



Google with 3D Point Cloud



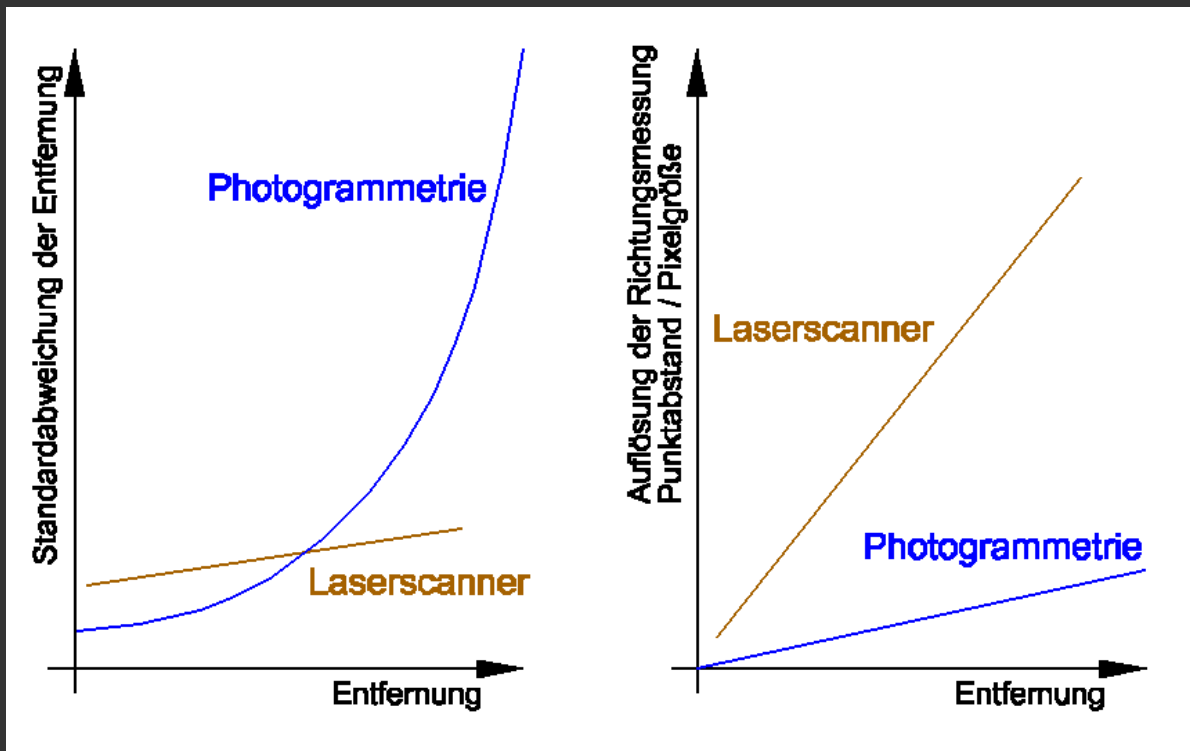


Google with 3D Point Cloud





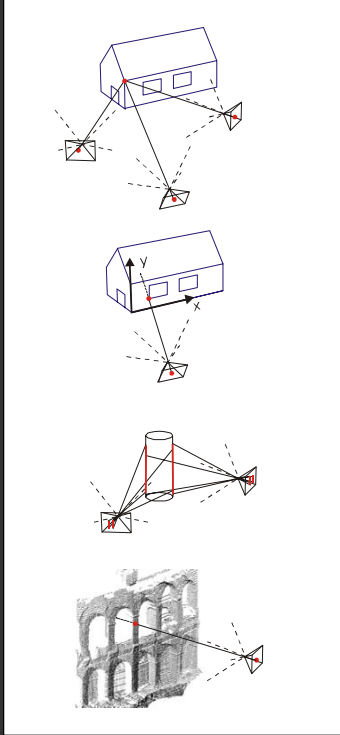
## Google with 3D Point Cloud



3D Monoplotting – Accuracy

3D Laser Scanning & Photogrammetry





Multi Image Measurement

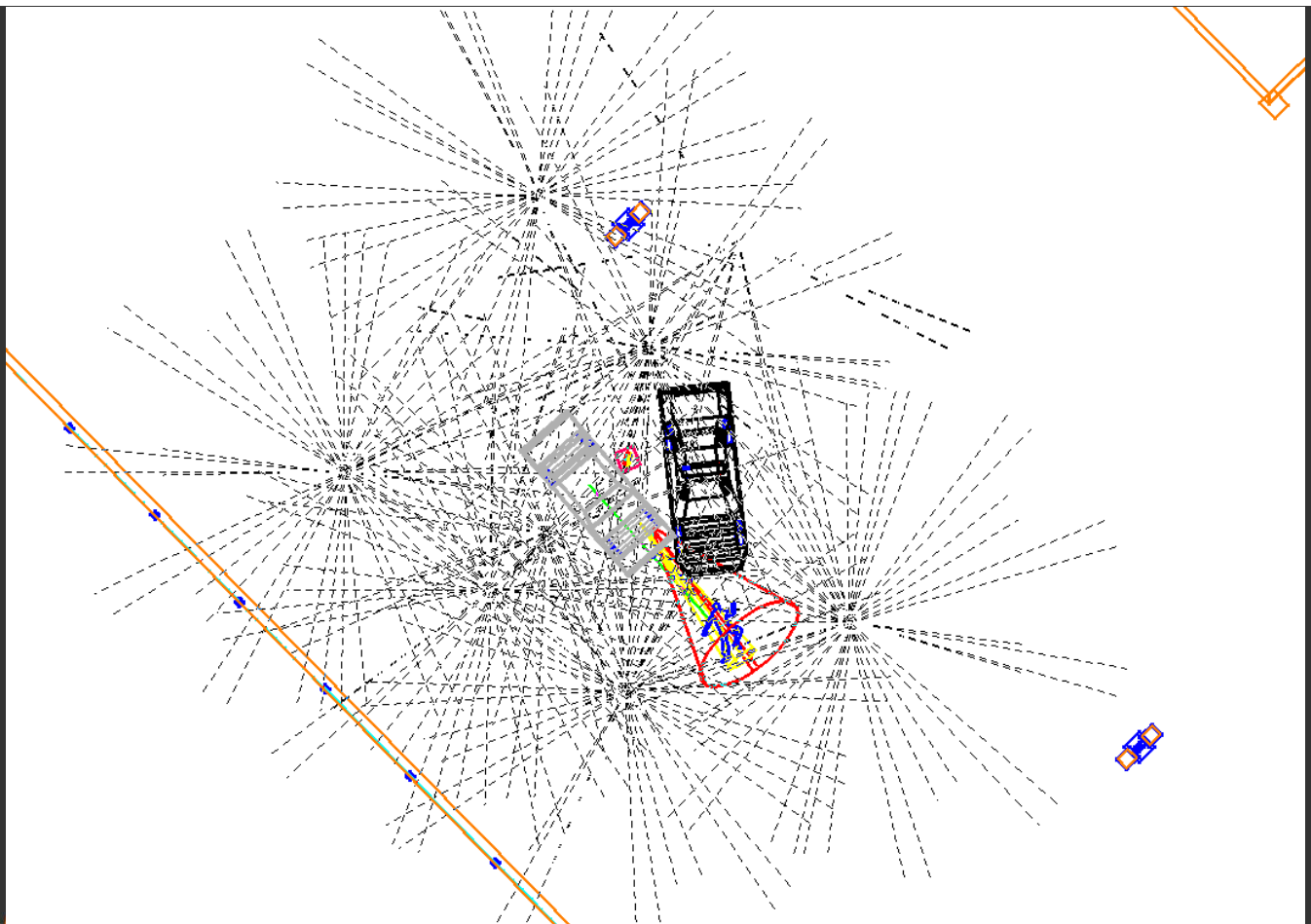
Measurement in Plane

Cylinder and Edge Measurement

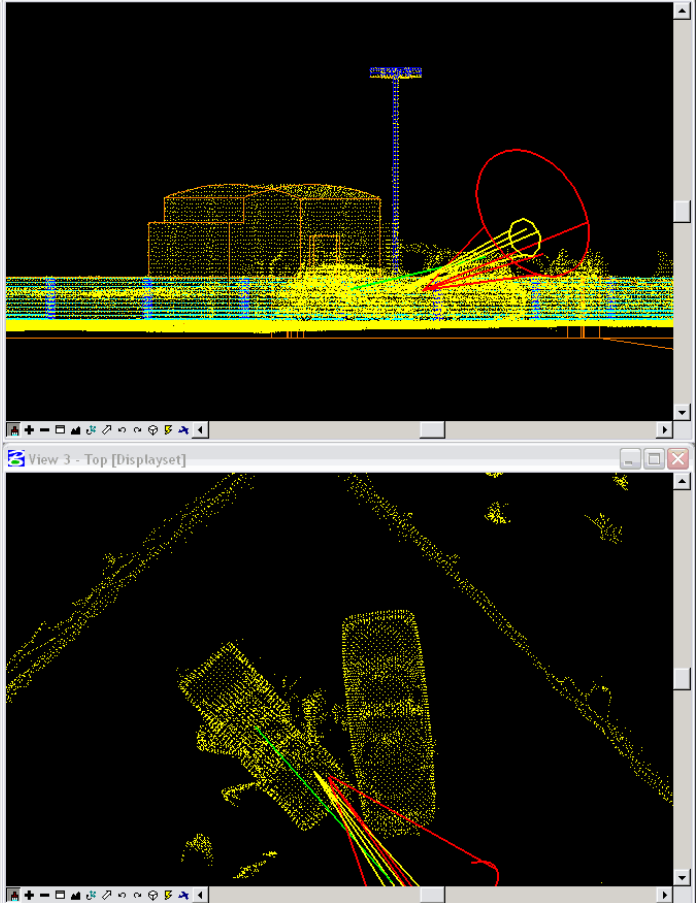
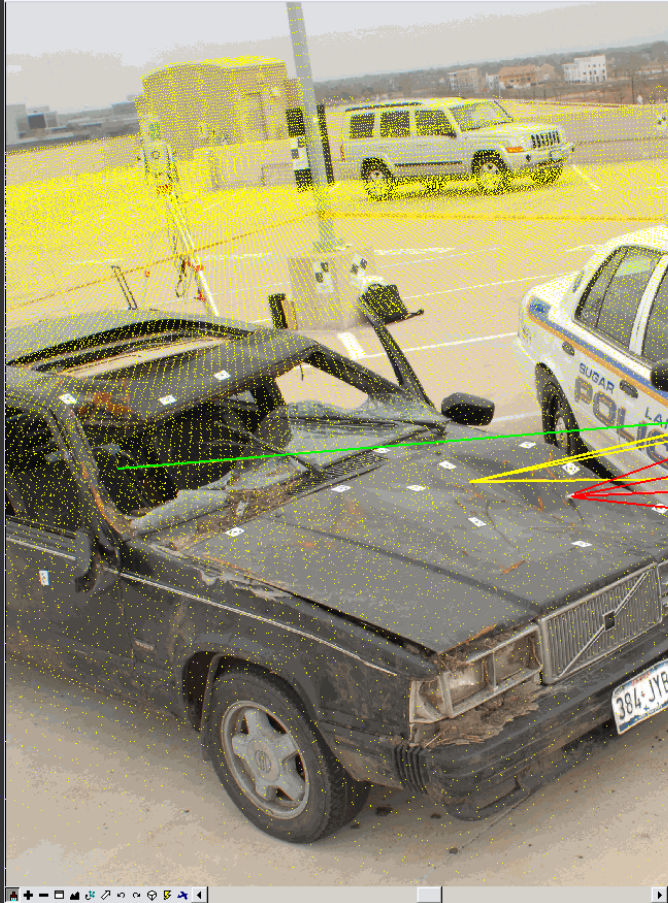
3D Intersection with Pointcloud



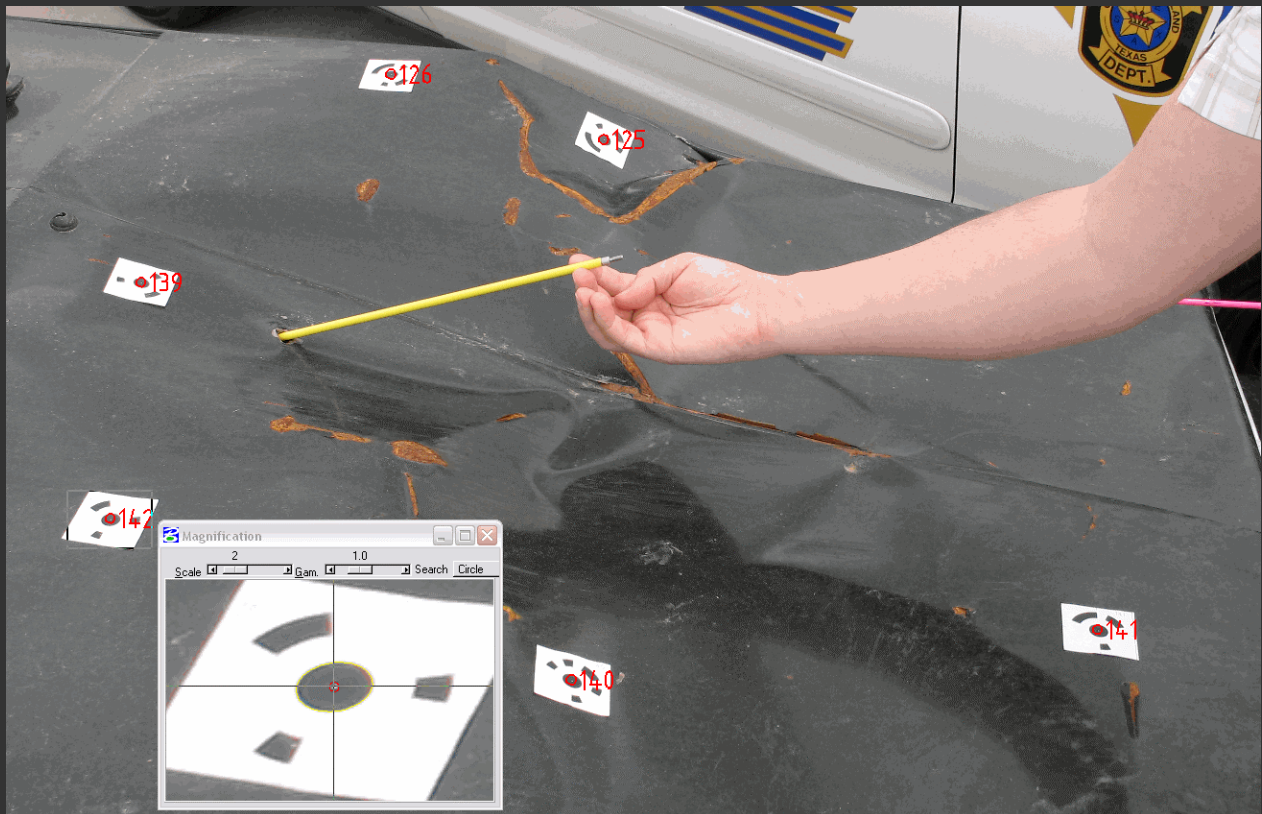
## PHIDIAS Measurement Methods



Overview Scanner / Camera Positions



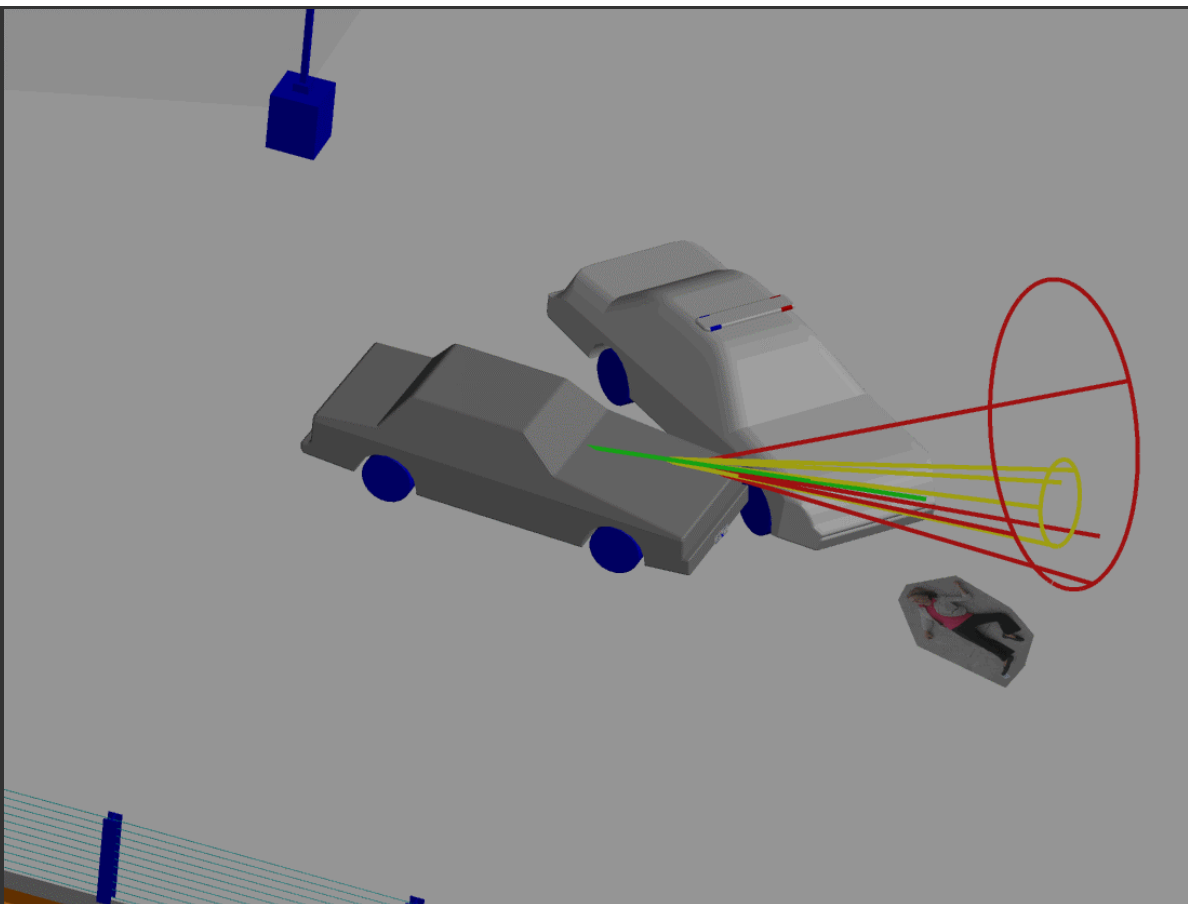
## PHIDIAS 3D Monoplotting



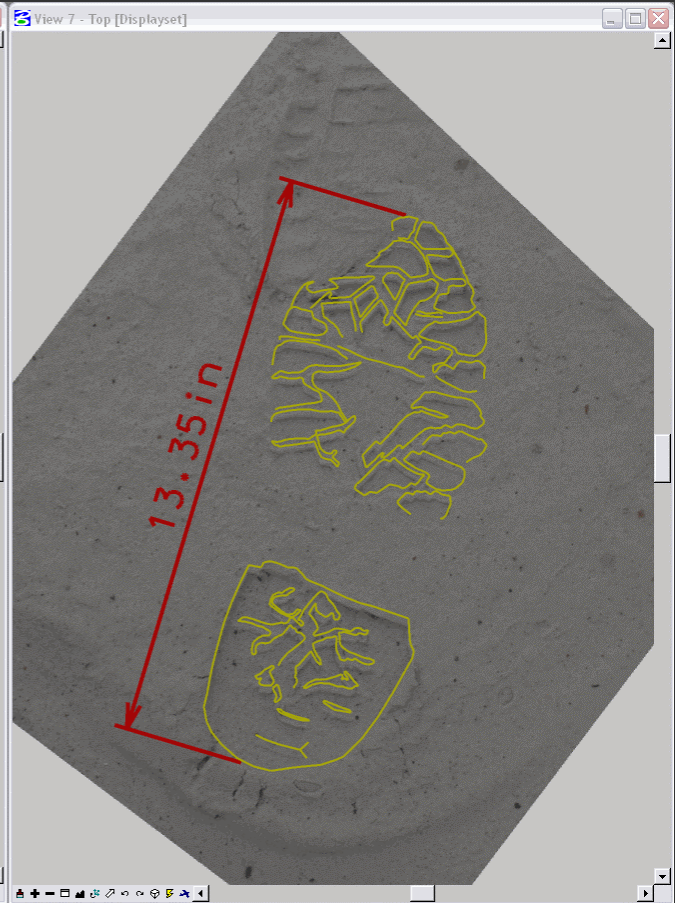
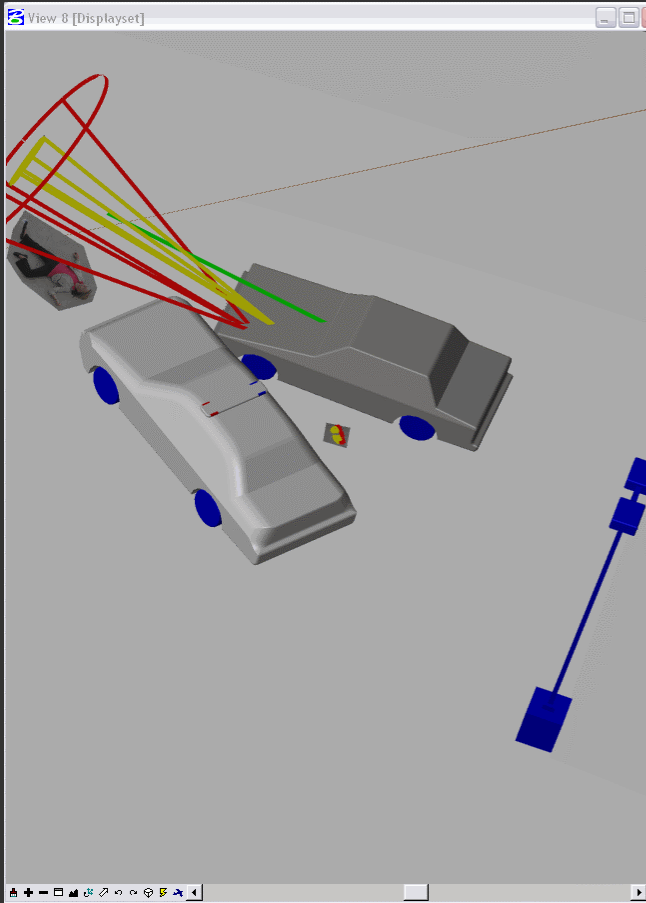
## PHIDIAS freehand Detail Photograph



PHIDIAS 3D Model



PHIDIAS Simulation Trajectories



PHIDIAS Detail Footprint



PHIDIAS Animation



Thank you  
for your attention!



**RIEGL**  
LASER MEASUREMENT SYSTEMS

# “Mobile Laser Scanning” Anwendungen

Oldenburger 3D Tage 2007

Nikolaus Studnicka  
Peter Rieger  
Andreas Ullrich

RIEGL Laser Measurement Systems GmbH  
[www.riegl.com](http://www.riegl.com)



# “Mobile Laser Scanning” Anwendungen

- Grundlagen
- Mobile Laser Scanning am Auto (2D Scanner, Japan)
- Mobile Laser Scanning am Auto (3D Scanner, Österreich)
- Airborne Laser Scanning kombiniert mit Terrestrischem Laser Scanning (Österreich)
- Mobile Laser Scanning am Boot (2D Scanner, Frankreich)



Inhalt

	<b>TLS</b> Terrestrisches Laser Scanning	<b>MLS</b> Mobiles Laser Scanning	<b>ALS</b> "Airborne" Laser Scanning
<b>Datenformat</b>	Bild basierend	Linien basierend	Linien basierend
<b>Registrierung</b>	Per Reflektoren oder Nutzdaten	<ul style="list-style-type: none"> <li>• online per INS/GPS Aufnahme</li> <li>• Sensoren wie z.B. Rad Sensor</li> </ul>	online per INS/GPS Aufnahme der Trajektorie
<b>Messentfernung</b>	1m – 1000m	typ. bis 200m	500m – 1500m
<b>Registrierengenauigkeit</b>	typ 5mm	typ 2cm (DGPS)	typ 10cm (bis 2cm bei ICP auf Referenzmodelle)
<b>Aufnahmeart</b>	stop-and-go		go



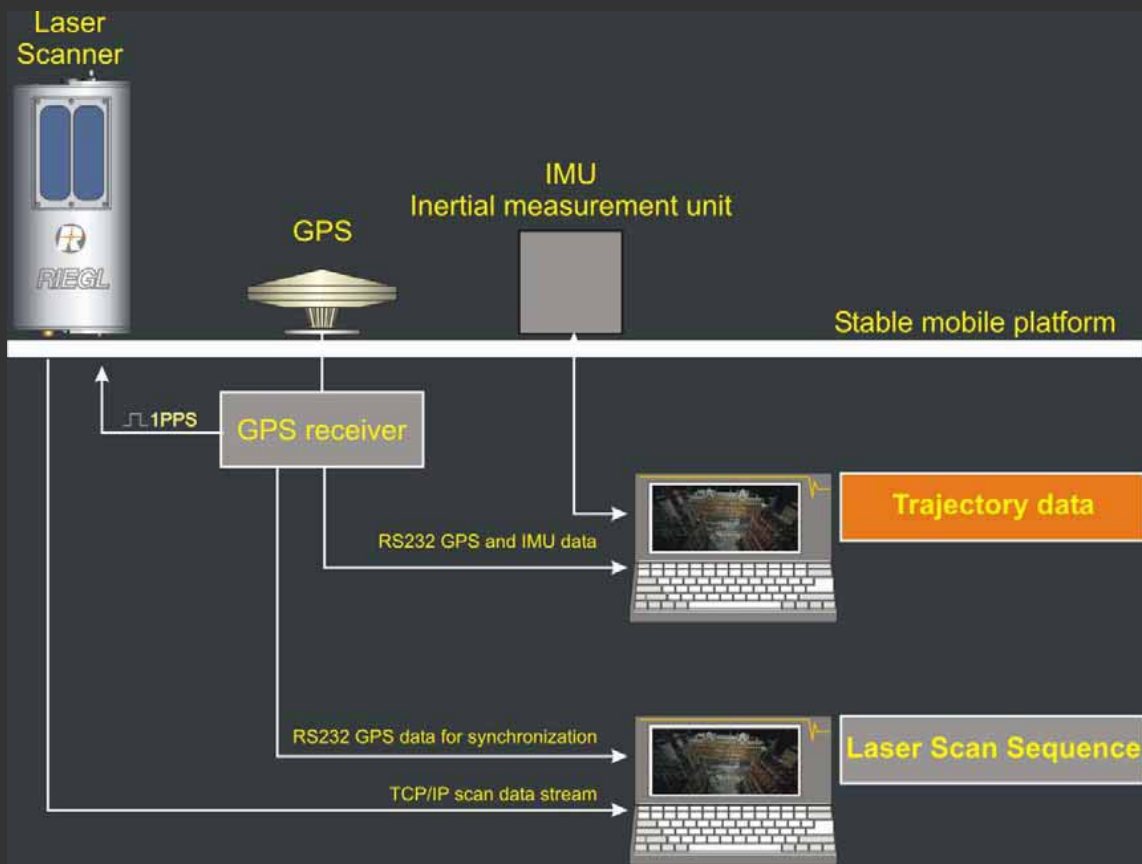
## Einteilung TLS / MLS / ALS

	<b>TLS</b> Terrestrisches Laser Scanning	<b>MLS</b> Mobiles Laser Scanning	<b>ALS</b> "Airborne" Laser Scanning
<b>Registrierung</b>	<ul style="list-style-type: none"> <li>• mit vielen Reflektoren (per Totalstation ect.)</li> <li>• mit einem Reflektor (back sighting) &amp; Eigenposition</li> <li>• ohne Reflektoren per ICP (iterative closest point) Algorithmus ect.</li> </ul>	<ul style="list-style-type: none"> <li>• Aufnahme der Laser Daten inklusive Zeitstempel</li> <li>• Aufnahme der Trajektorie (per INS/GPS)</li> <li>• Verbesserung der Registrierung durch Ausgleichung an stationär aufgenommenen Referenzobjekten</li> </ul>	<ul style="list-style-type: none"> <li>• Aufnahme der Laser Daten inklusive Zeitstempel</li> <li>• Aufnahme der Trajektorie (per INS/GPS)</li> </ul> <p>Verbesserung der Registrierung durch Streifenausgleich:</p> <ol style="list-style-type: none"> <li>1. Zur internen Systemkalibrierung (6 Parameter)</li> <li>2. Nutzdatenverbesserung (3 Translation- &amp; 3 Rotations Parameter je Flugsteifen)</li> <li>3. Ausrichtung an stationär aufgenommenen Kontrollobjekte</li> </ol>

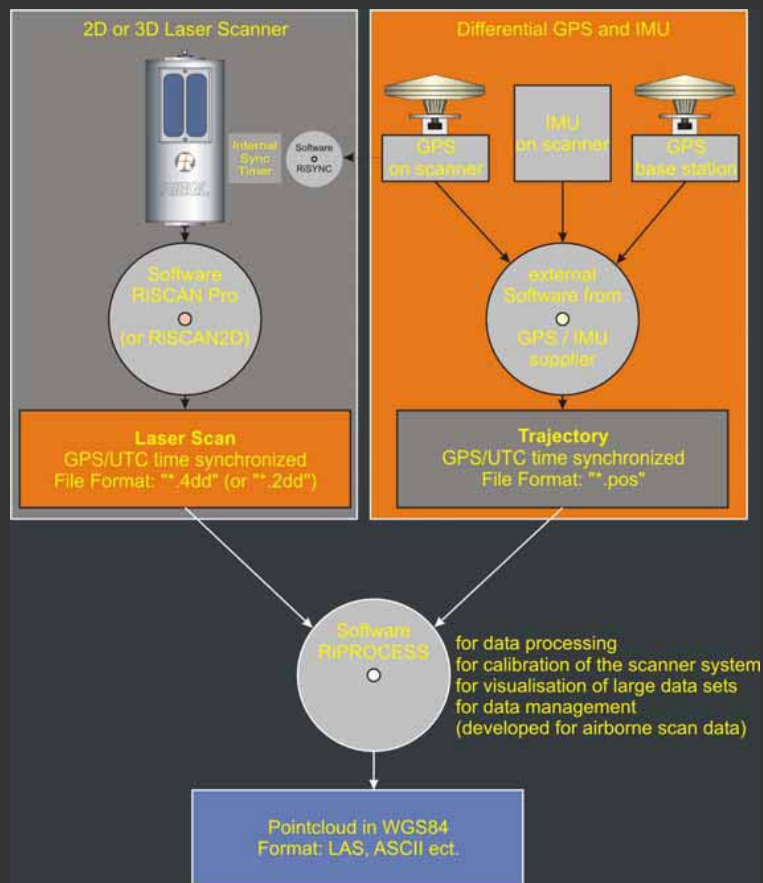
Definition Trajektorie: Ort und Orientierung als Funktion der Zeit (zeitdiskret)



## Registrierung TLS / MLS / ALS



## MLS System Konfiguration



## MLS Workflow



## Trajectory File (\*.pos)

The \*.pos file contains information about the position and the orientation of the moving platform. The default setup is as follows:

1. Column: UTC timestamp in seconds [seconds of day]
2. Column: Latitude [deg]
3. Column: Longitude [deg]
4. Column: Height [m]
5. Column: Roll [deg]
6. Column: Pitch [deg]
7. Column: Yaw [deg]

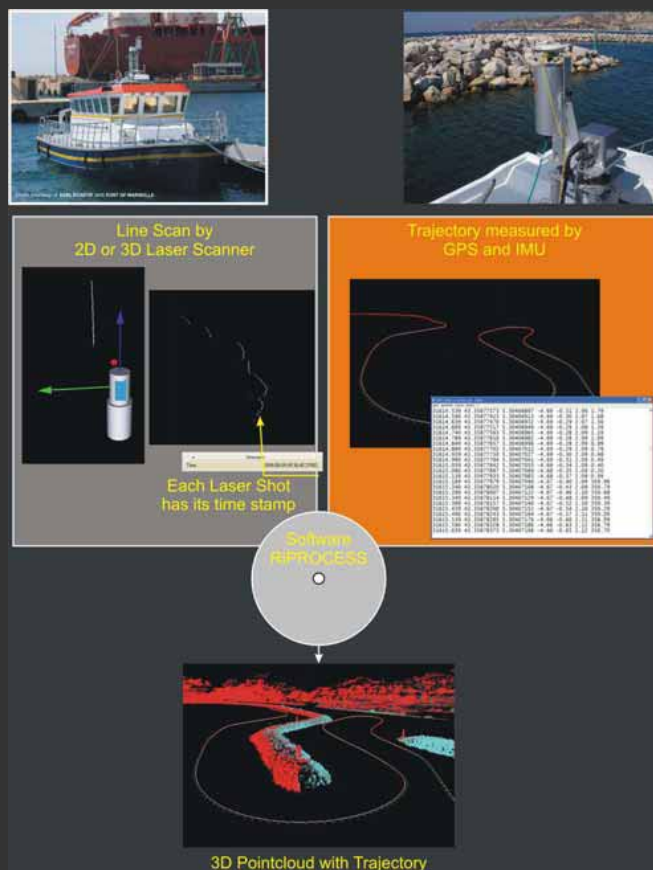
The values are separated by blanks

Example:

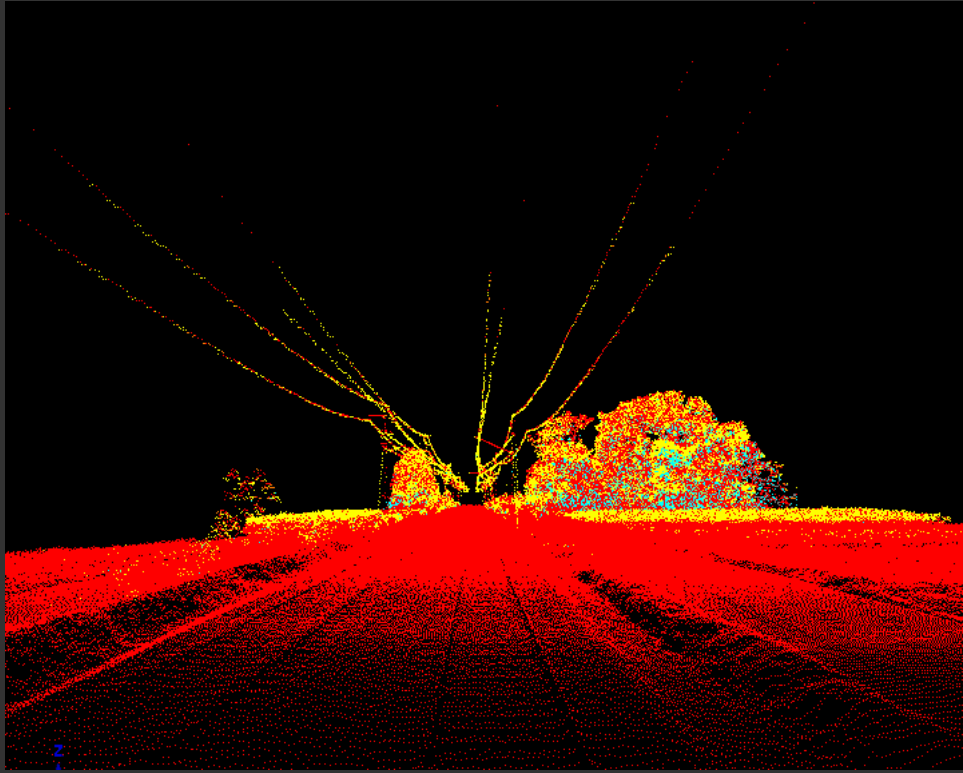
```
50759.0010 48.33841614 15.93149532 471.005 -0.8156 7.1238 71.1383
50759.0020 48.33841616 15.93149556 471.004 -0.8118 7.1230 71.1393
50759.0030 48.33841617 15.93149579 471.002 -0.8081 7.1214 71.1409
50759.0040 48.33841619 15.93149602 471.000 -0.8039 7.1195 71.1411
```



## MLS Trajektorie - Definition



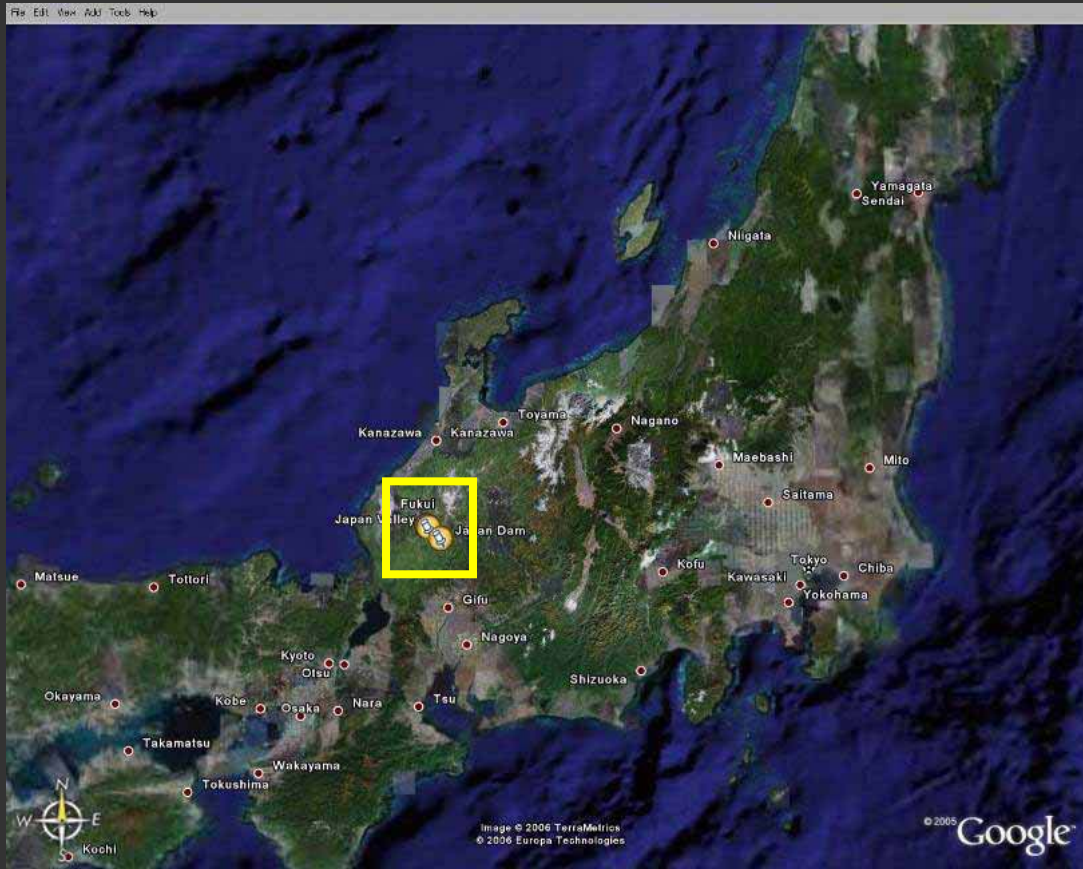
## MLS Beispieldaten



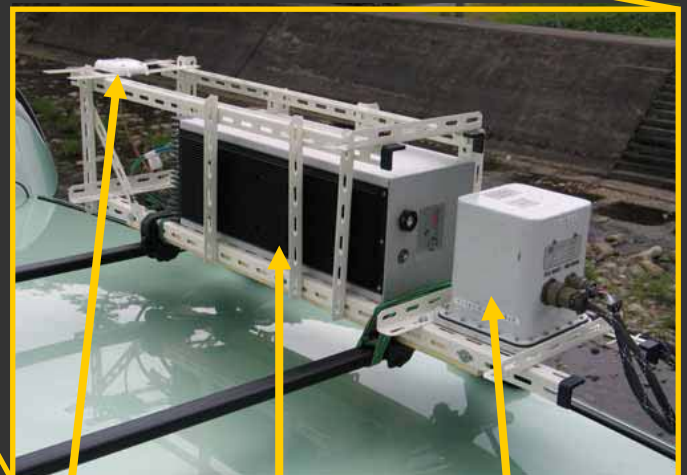
Punktewolkendaten, aufgenommen von einem Helikopter

MLS 2D Laser Scanner Q560 am Auto (Japan)





## Fallbeispiel MLS am Auto



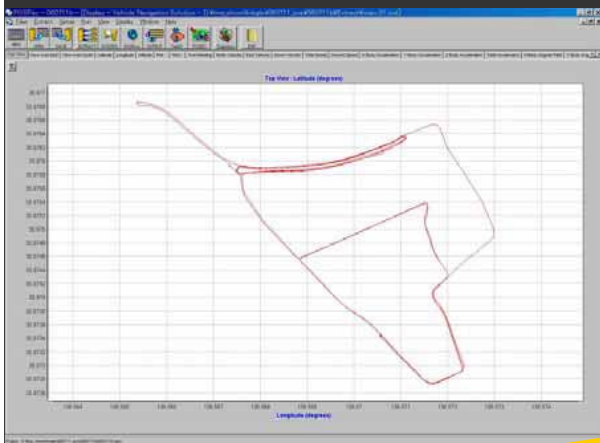
GPS

Laser Scanner Q560

IMU Applanix

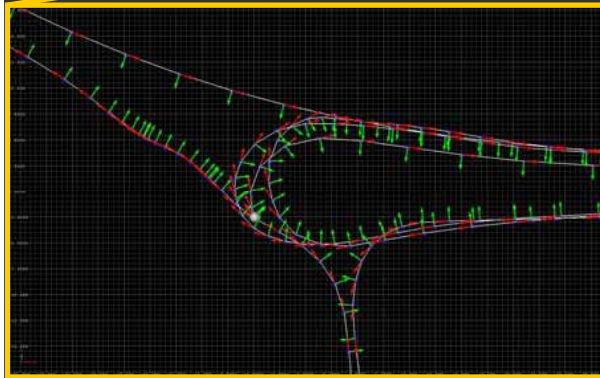
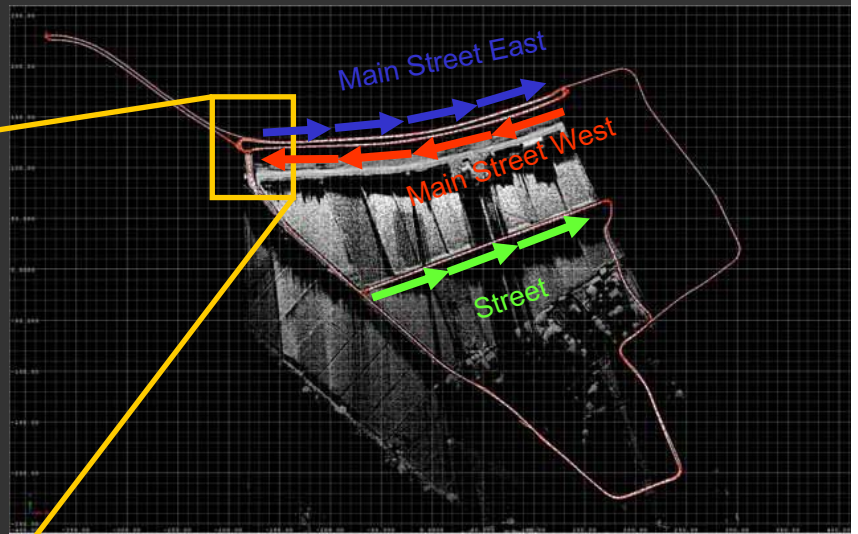


## Team & System Konfiguration

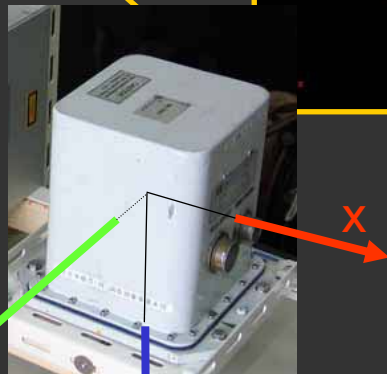
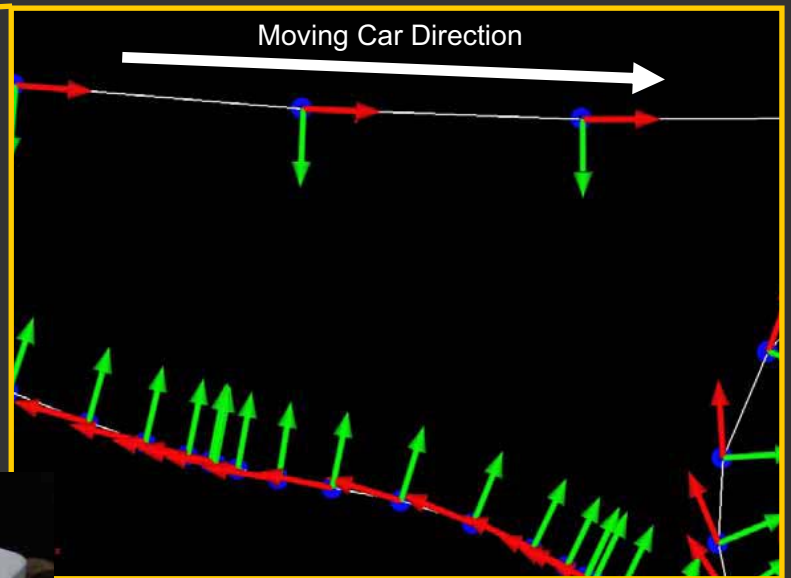


Applanix View of Trajectory

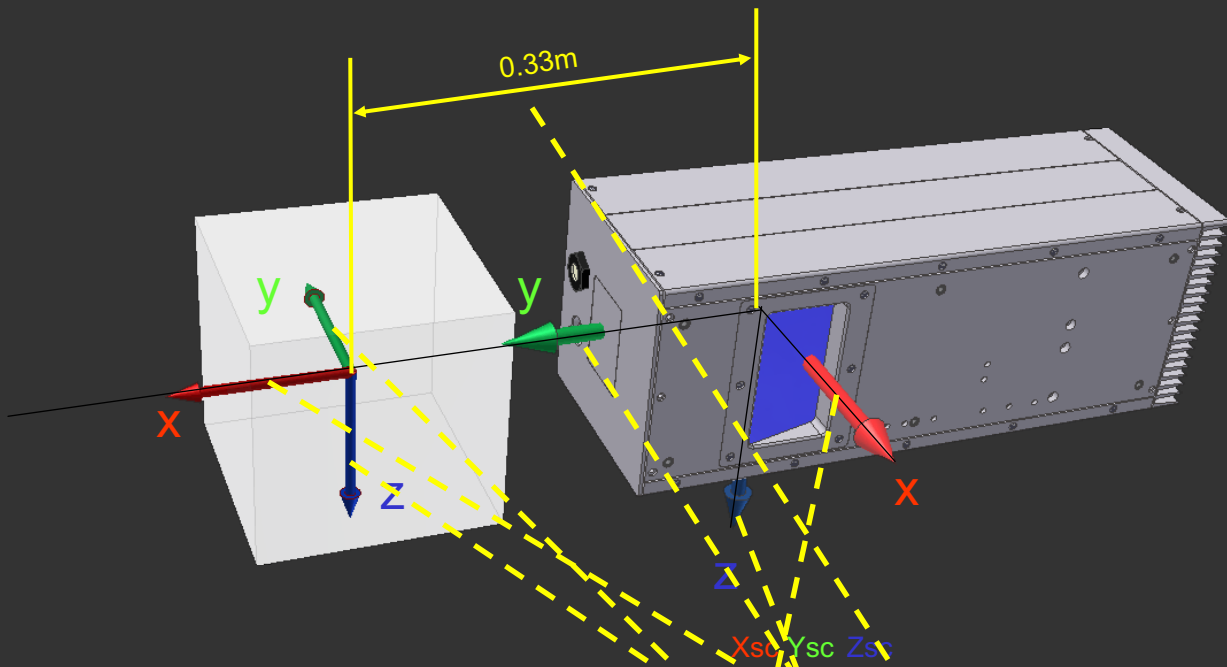
RiSCAN PRO View of Trajectory



Trajektorie



Trajektorie



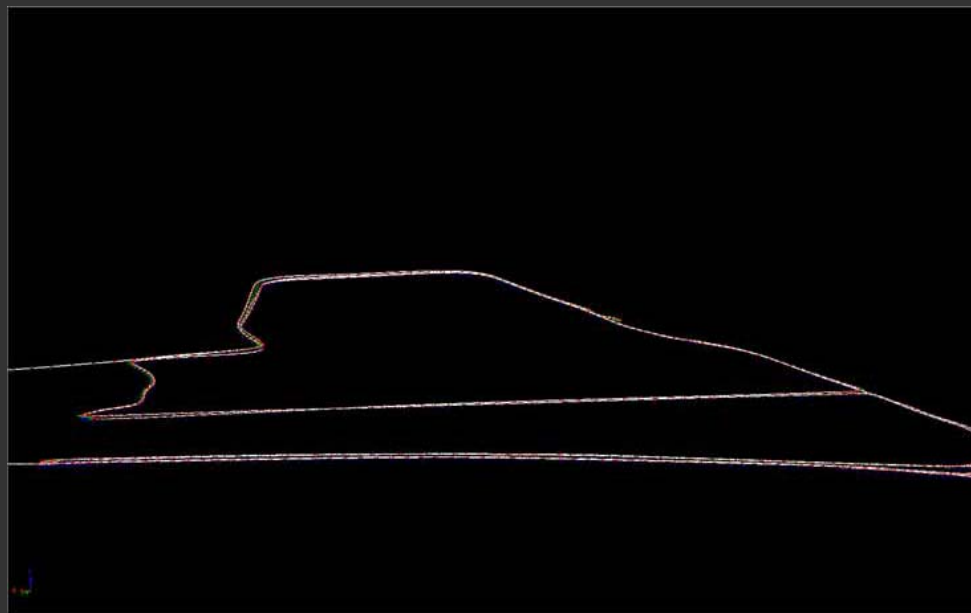
$$C_{IMU}^{SOCS} = \begin{pmatrix} x_{TRA}^{Ximu} & y_{TRA}^{Yimu} & z_{TRA}^{Zimu} & 1 \\ 0 & 0 & 0 & 1 \end{pmatrix} = \begin{pmatrix} 0 & 1 & 0 & -0.33 \\ -1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

delta Ximu

Rotation Translation



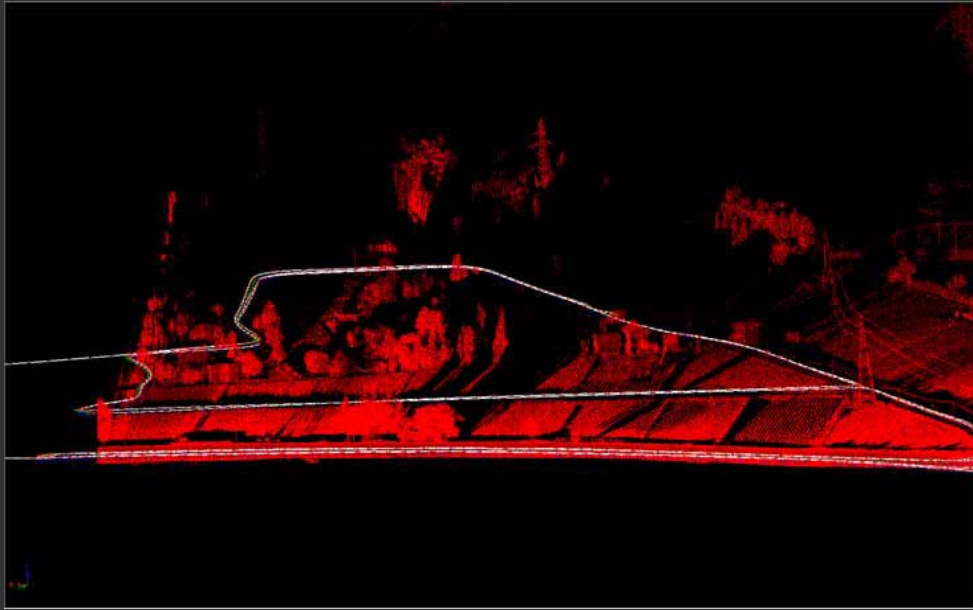
## Transformation Matrix – IMU / Scanner Own Coordinate System



Trajectory of the Car



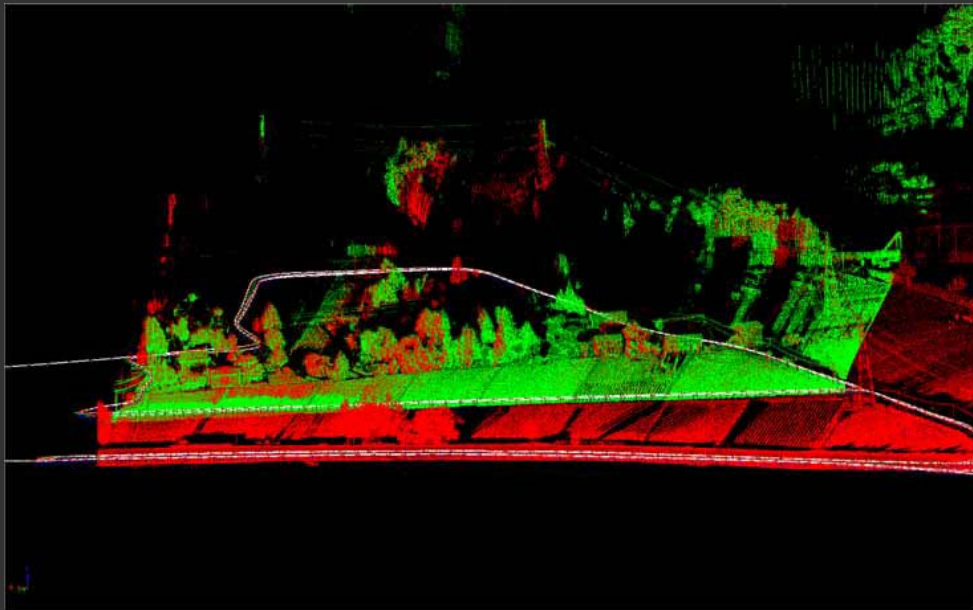
## Trajektorie



Trajectory of the Car & Main Street West



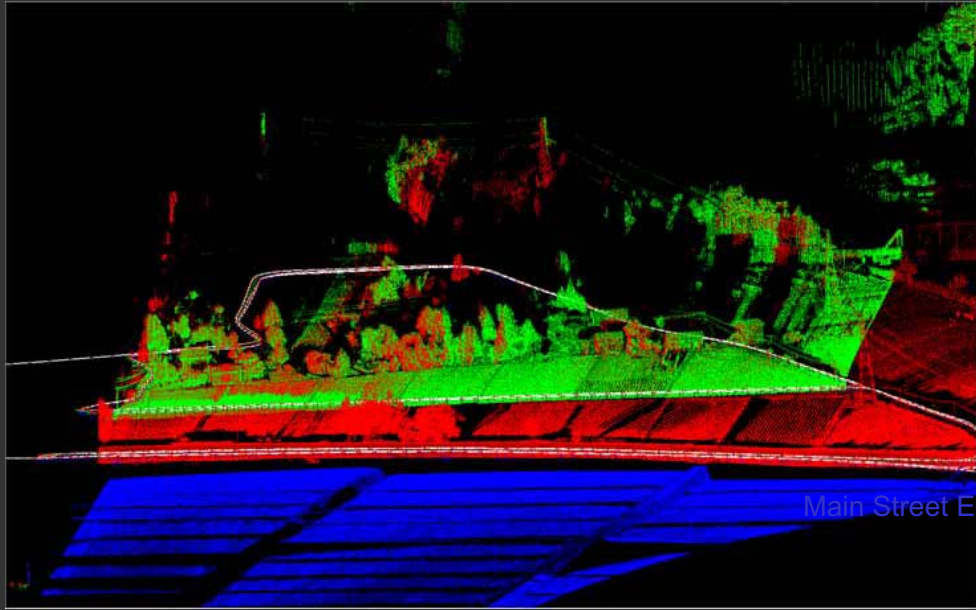
MLS Scan



Trajectory of the Car & Main Street West & Street



MLS Scan



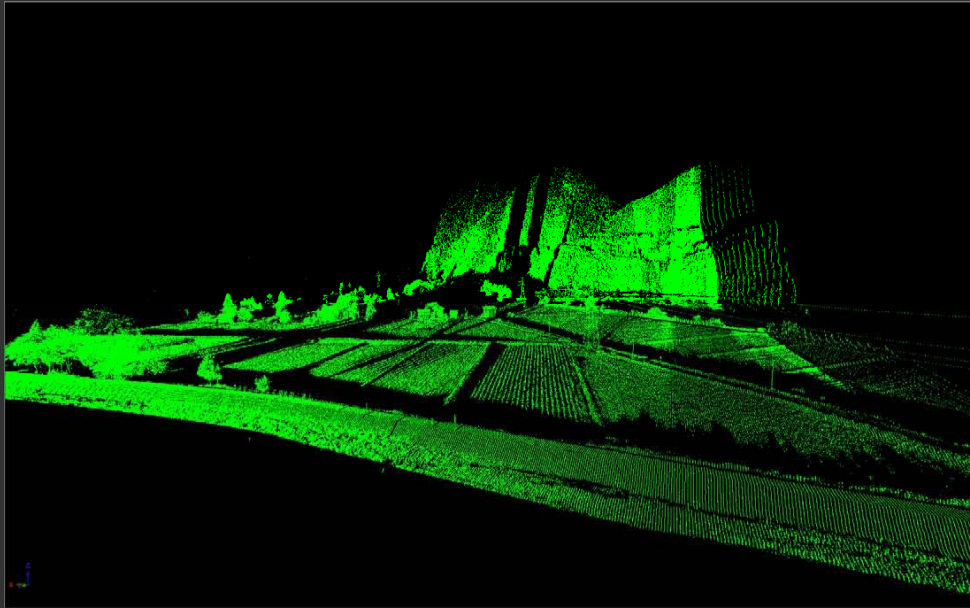
Trajectory of the Car & Main Street West & Street &



Erstes Ziel



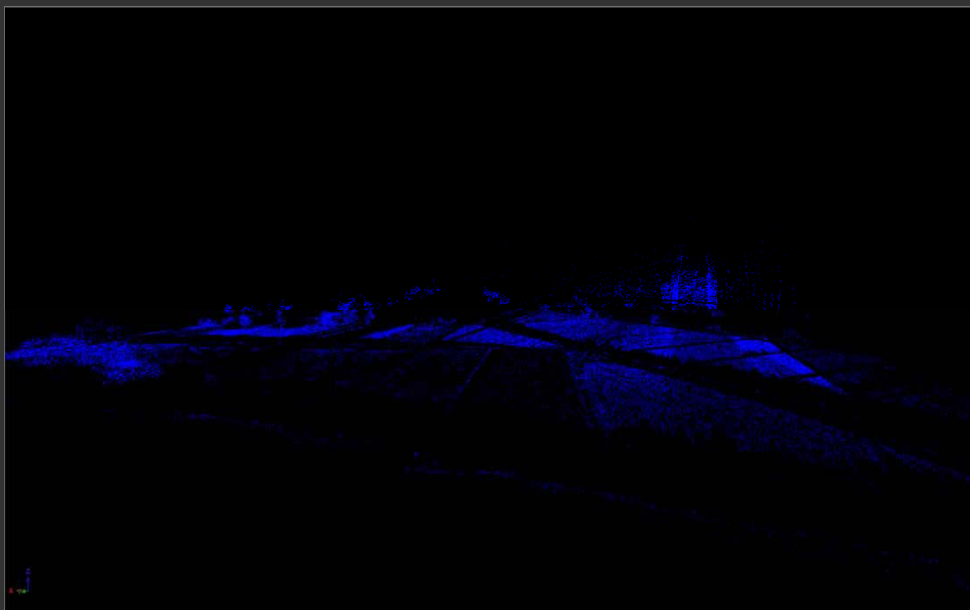
“Full Waveform” Analyse



Letztes Ziel



“Full Waveform” Analyse

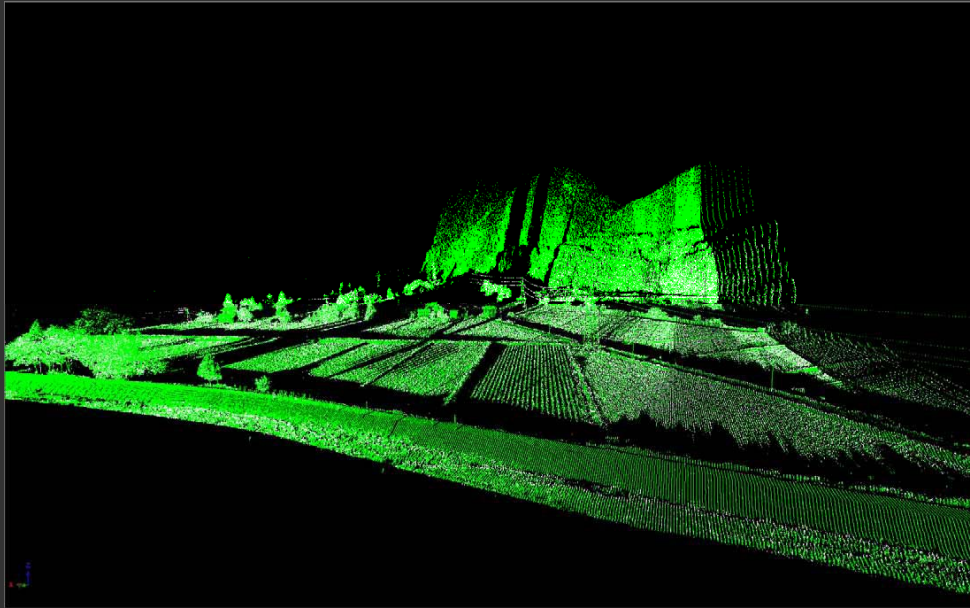


Alle anderen Ziele



“Full Waveform” Analyse

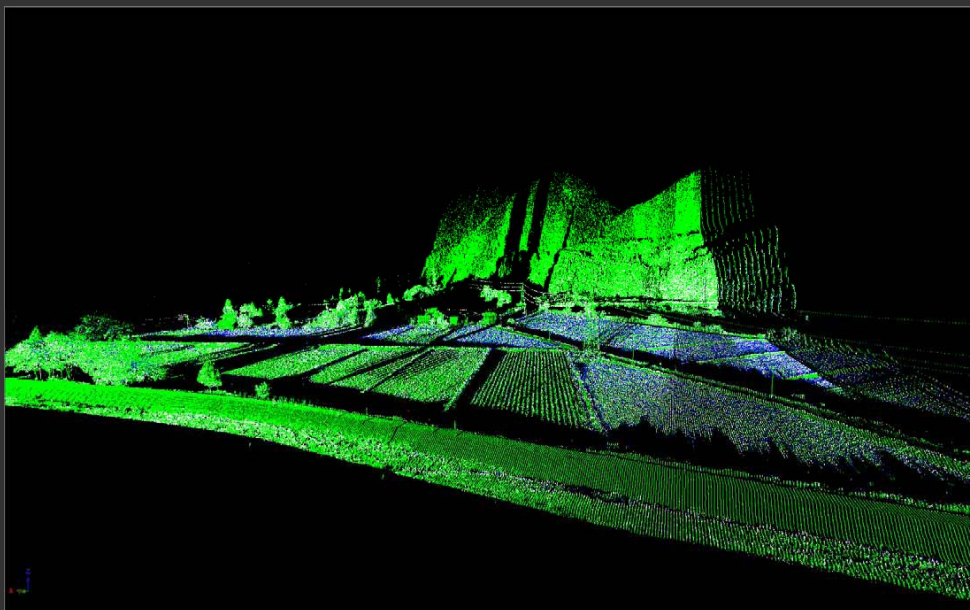




Erstes & Letztes Ziel



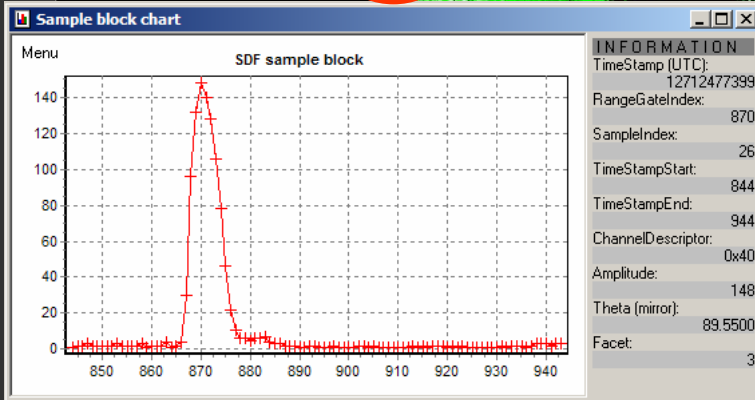
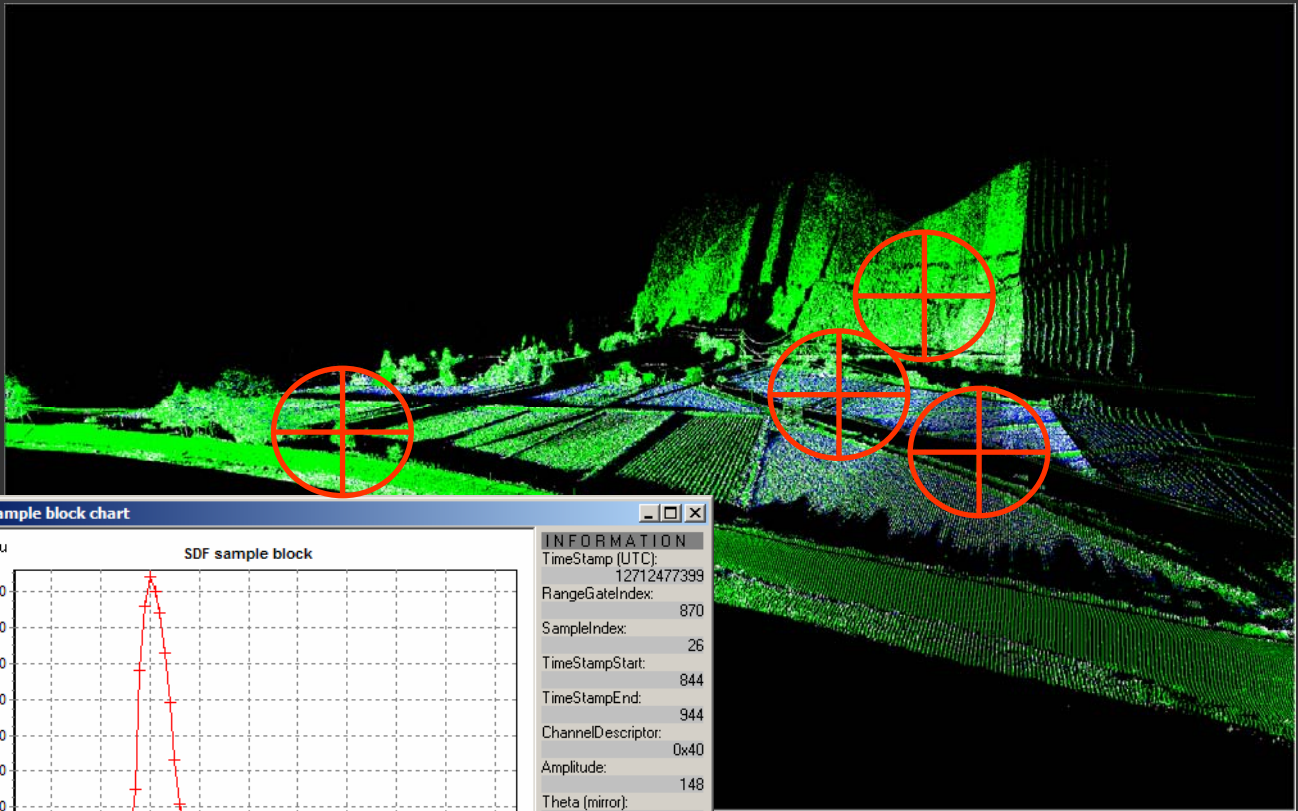
“Full Waveform” Analyse



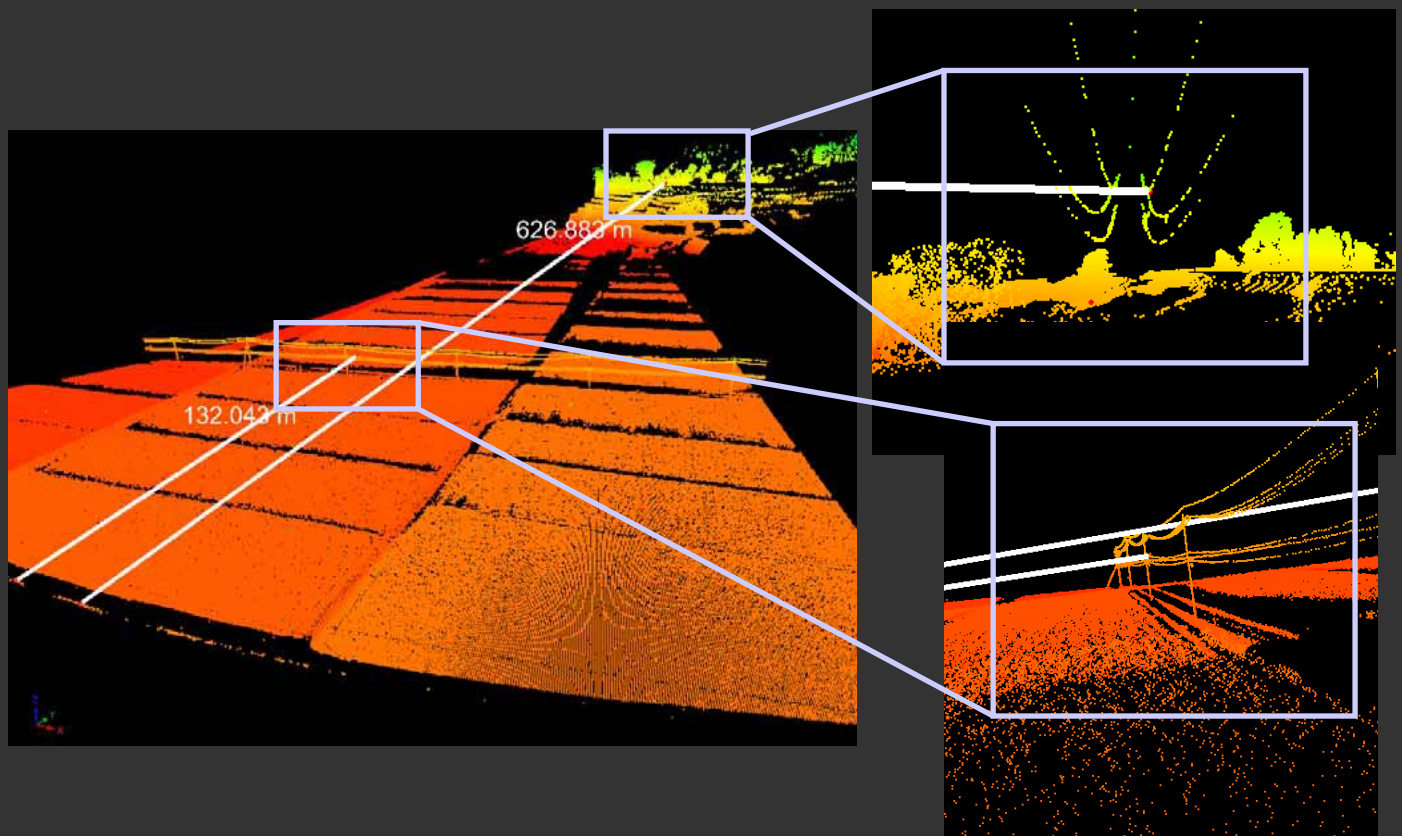
Alle Ziele



“Full Waveform” Analyse

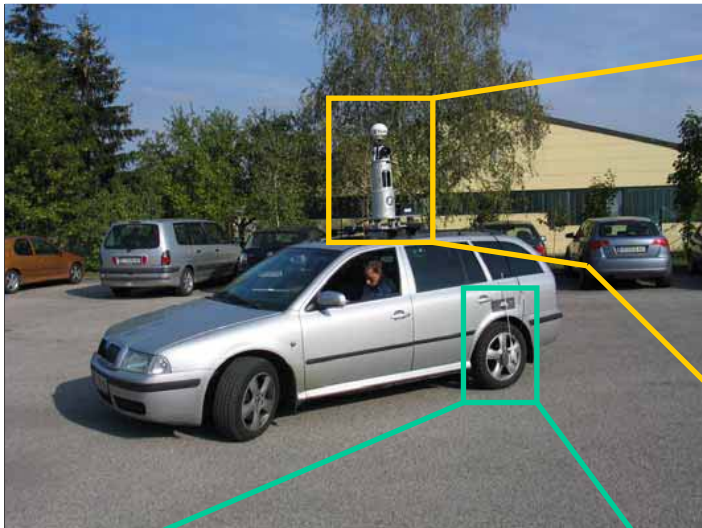


### “Full Waveform” Analyse



### Maximale Reichweite zu Hochspannungleitungen (50kHz)

# MLS 3D Laser Scanner Z420 am Auto (Österreich)



GPS

3D Laser Scanner Z420i

IMU Applanix



Rad Sensor

MLS 3D Laser Scanner Z420 am Auto



MLS 3D Laser Scanner Z420 am Auto

ALS 2D Laser Scanner Q560  
kombiniert mit TLS 3D Laser Scanner Z420 (Österreich)



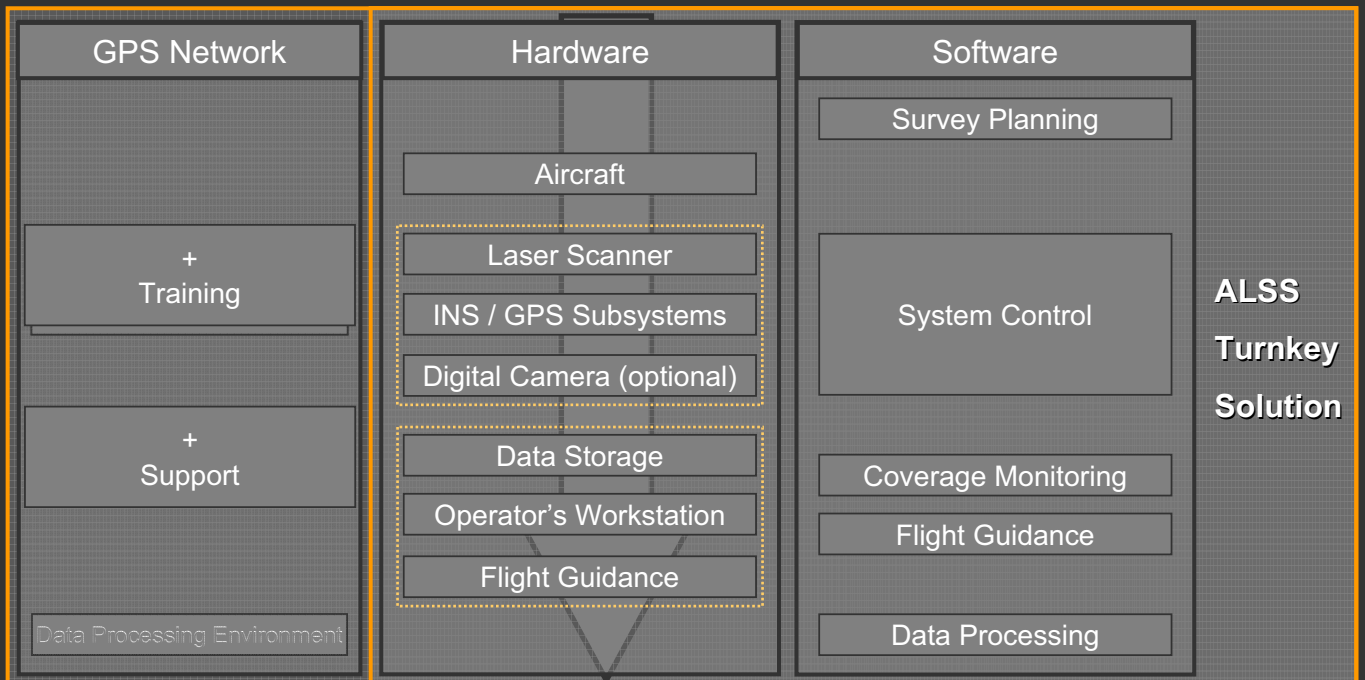


## Schlüsselfertiges System für ALS

- 1-2 Laser Scanner
- INS/GPS System
- Mittelformatkamera
- Flugzeug (DA42)



### Request for Airborne Laser Scanning Survey



Airborne Laser Scanning Data in WGS84

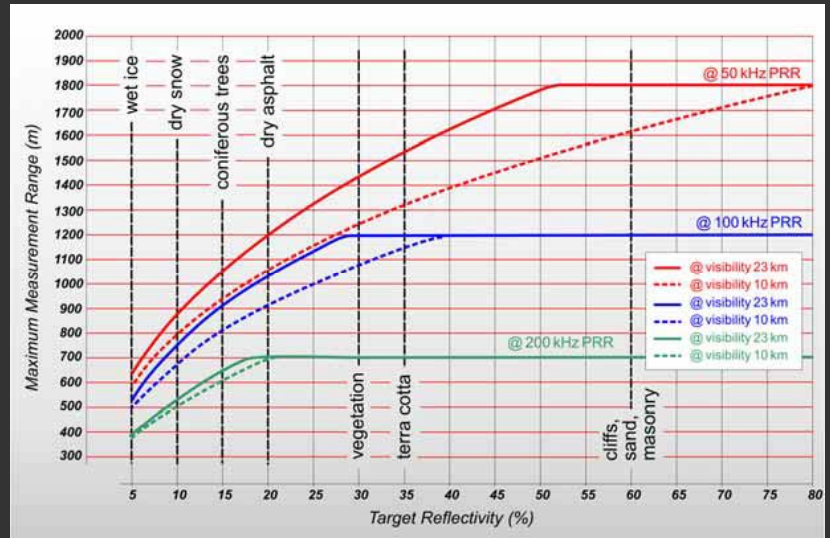


ALS System Komponenten

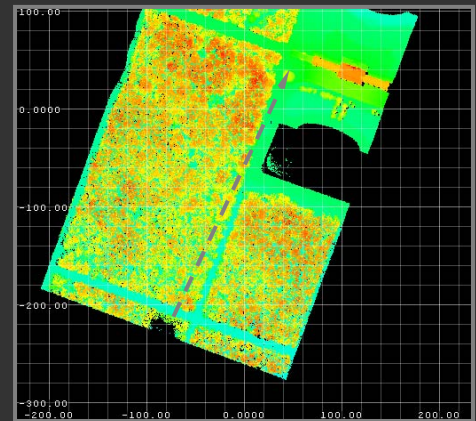
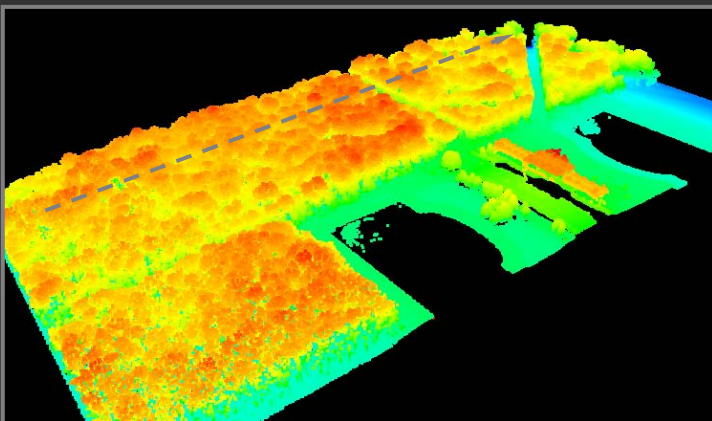
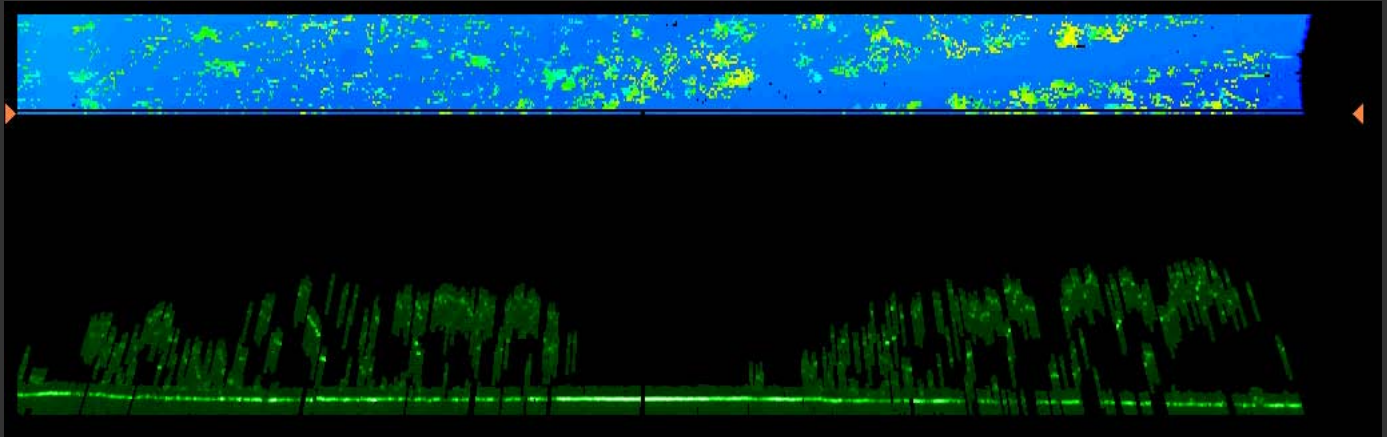
## Specifications RIEGL LMS-Q560

Measurement range	30 m - 1800 m at $\rho = 80\%$ 30 m - 1200 m at $\rho = 20\%$
Ranging accuracy	20 mm
multi-target resolution	down to 0.5 m
Measurement rate	50 000 - <b>200 000 meas/s</b> (burst rate) up to 133 000 meas/ s (average)
Scan range	45°(up to 60°)
Scan speed	Up to 160 lines / sec
Synchronization	GPS PPS & serial IF
Size / weight	560 x 200 x 217 mm / 20 kg
Laser safety	Laser class 1 / wavelength near infrared

## Maximum Measurement Range vs Target Reflectivity and Measurement Rate



## Laser Scanner Spezifikation RIEGL LMS-Q560



## Darstellung der Echosignale pro Scanlinie

ALS Fallbeispiel aus dem Paper  
„Full-waveform airborne laser scanning  
as a tool for archaeological reconnaissance“

In: Campana S., Forte M. (eds.), From Space to Place.  
Proceedings of the 2nd International Conference on  
Remote Sensing in Archaeology.  
BAR International Series 1568, 2006, 99-106.

Autoren:

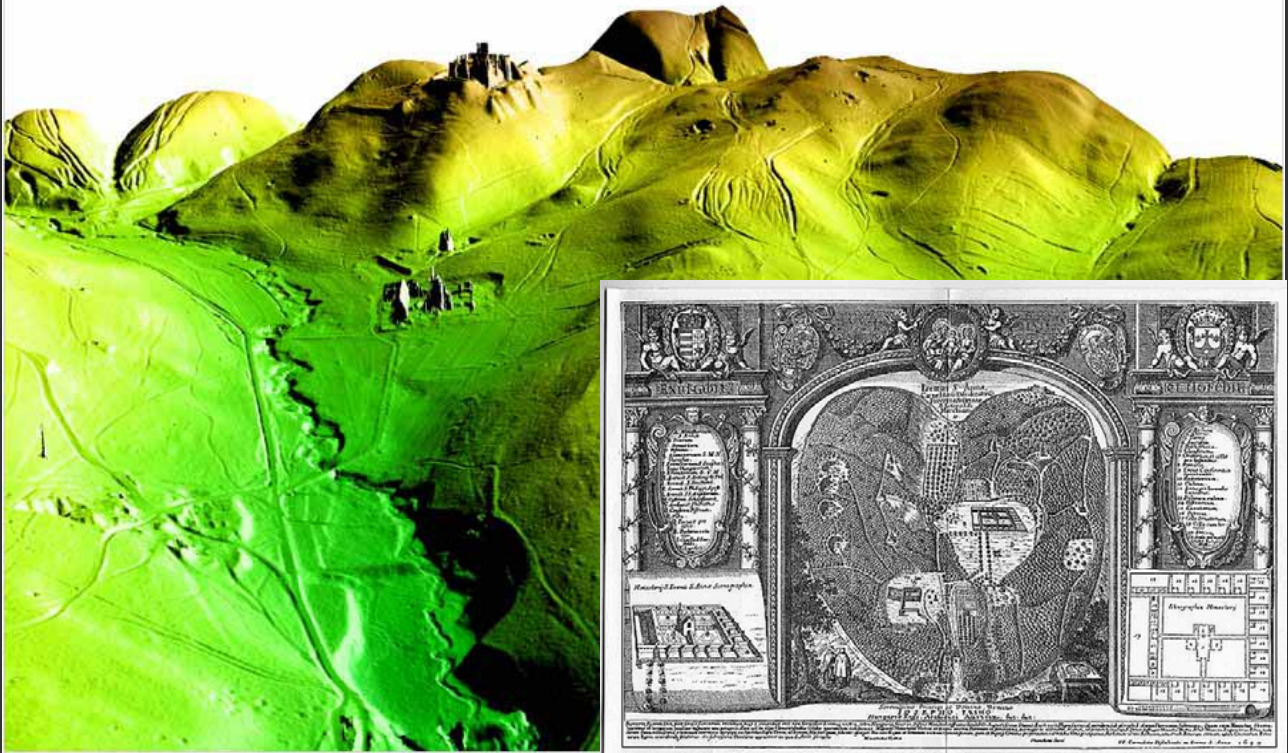
Michael Doneus [michael.doneus@univie.ac.at]  
Christian Briebe [cb@ipf@tuwien.ac.at]



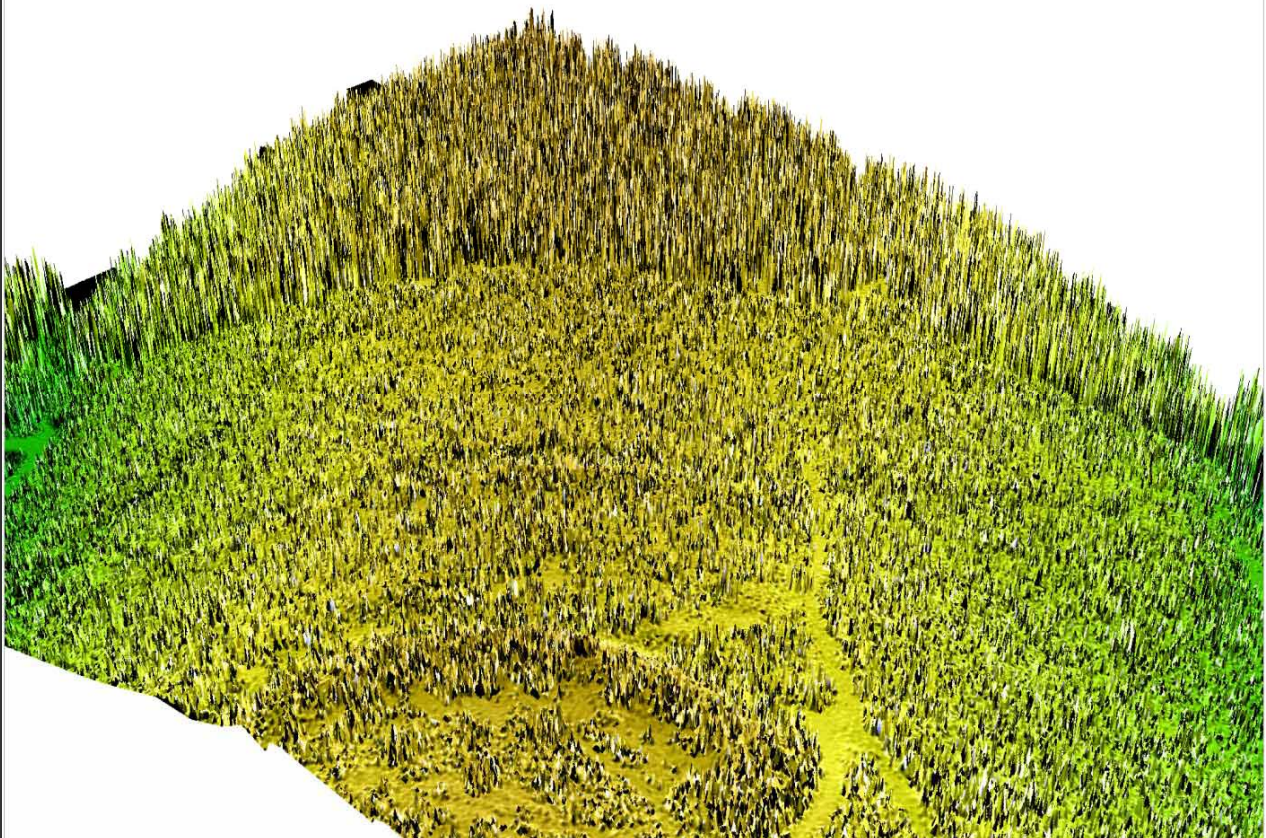
ALS Fallbeispiel mit Full Waveform DSM



ALS Fallbeispiel mit Full Waveform DSM

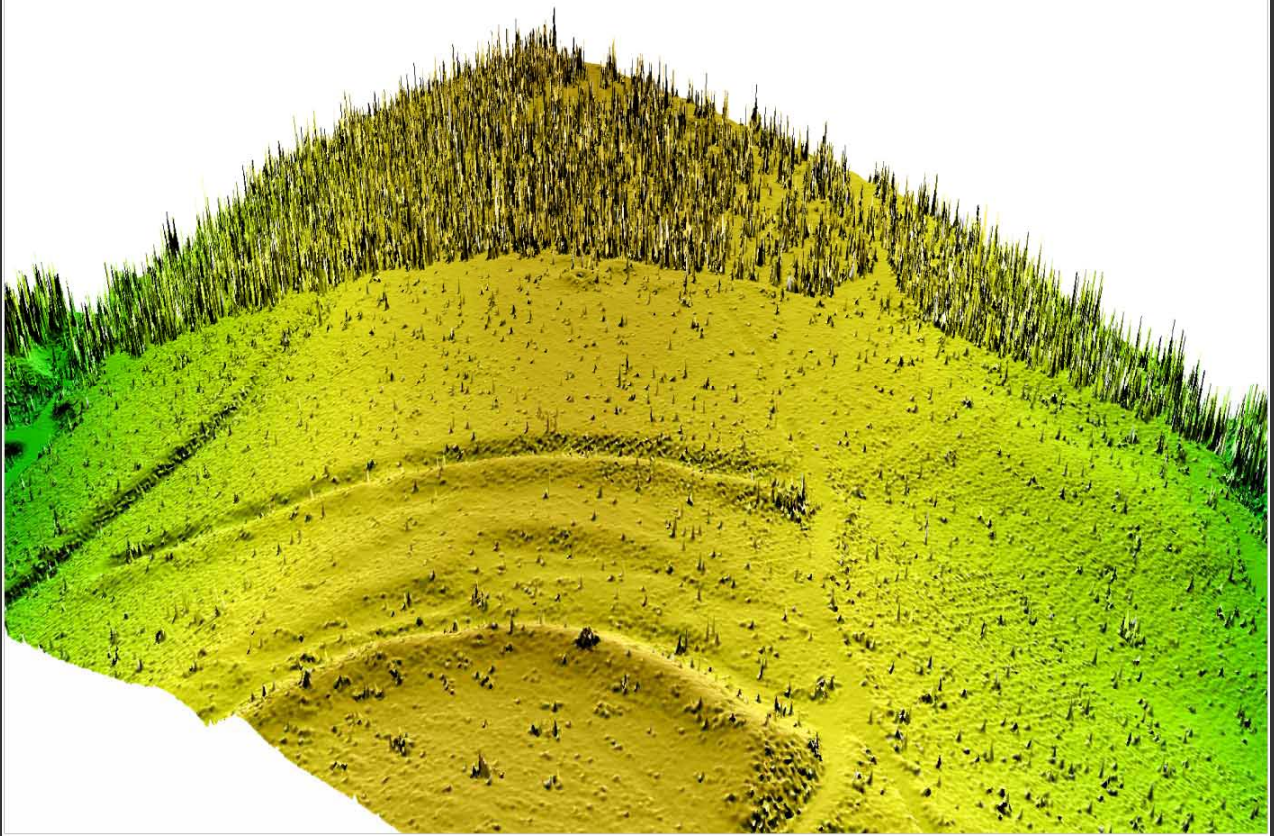


## ALS Fallbeispiel mit Full Waveform DSM

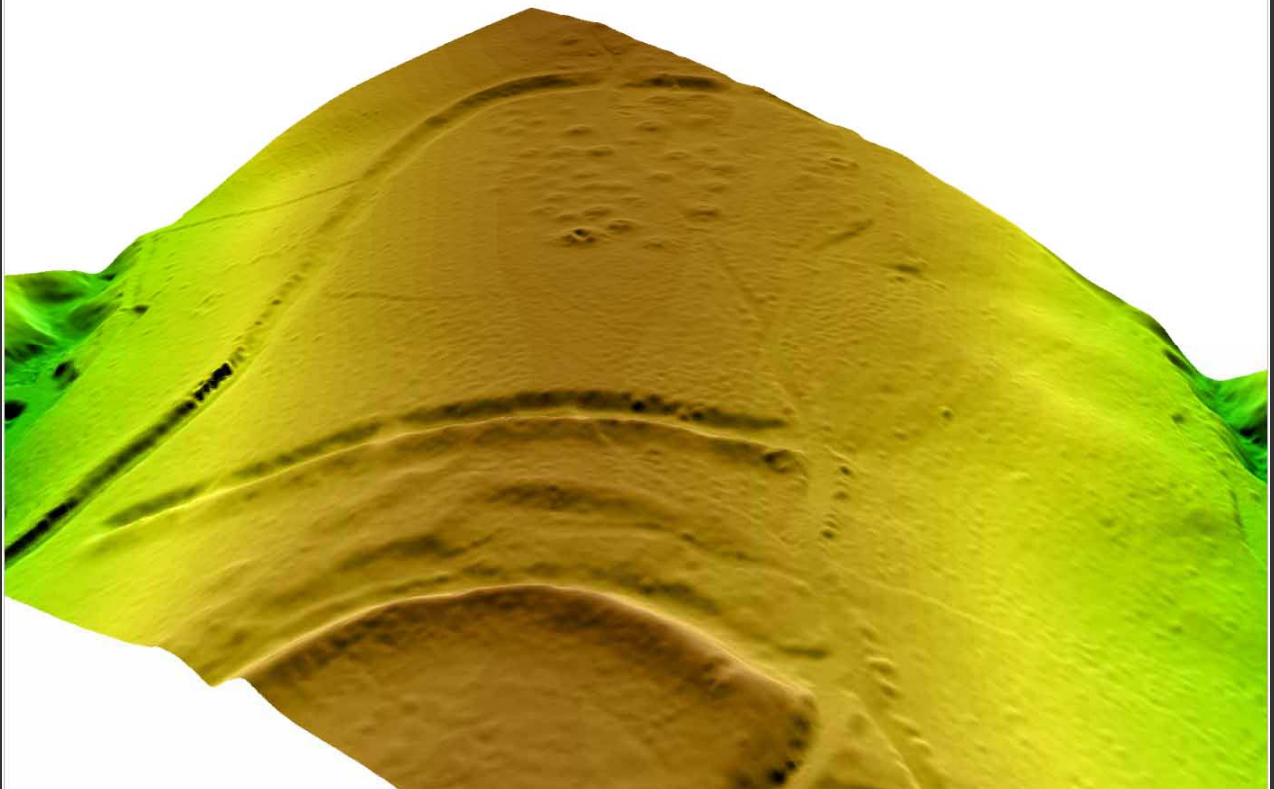


## 3D-Ansicht von runden Wällen- DSM

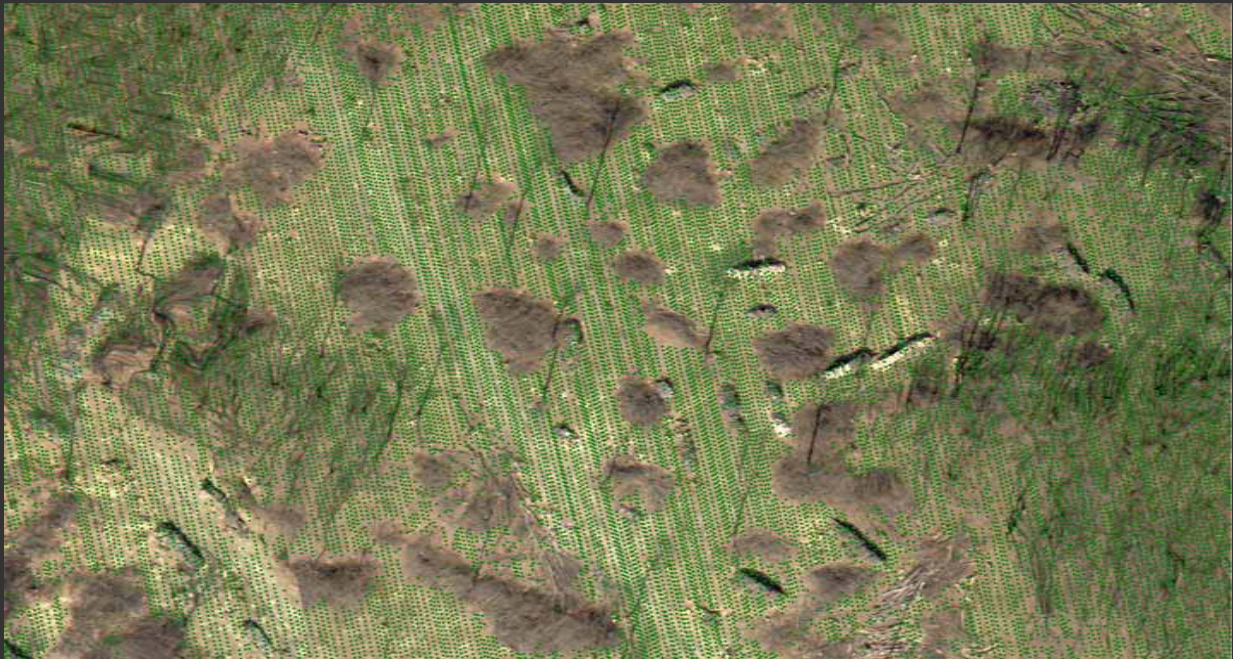




3D-Ansicht von runden Hügelgräber - ungefiltertes DTM

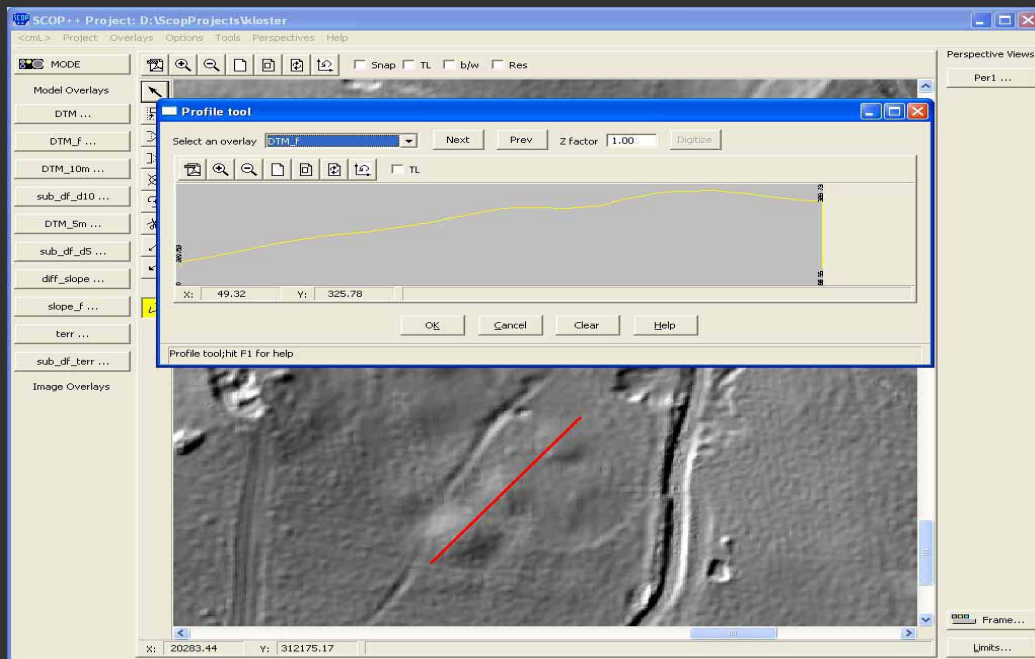


3D-Ansicht von runden Hügelgräber - gefiltertes DTM (Impulsbreite)



**RIEGL**  
LASER MEASUREMENT SYSTEMS

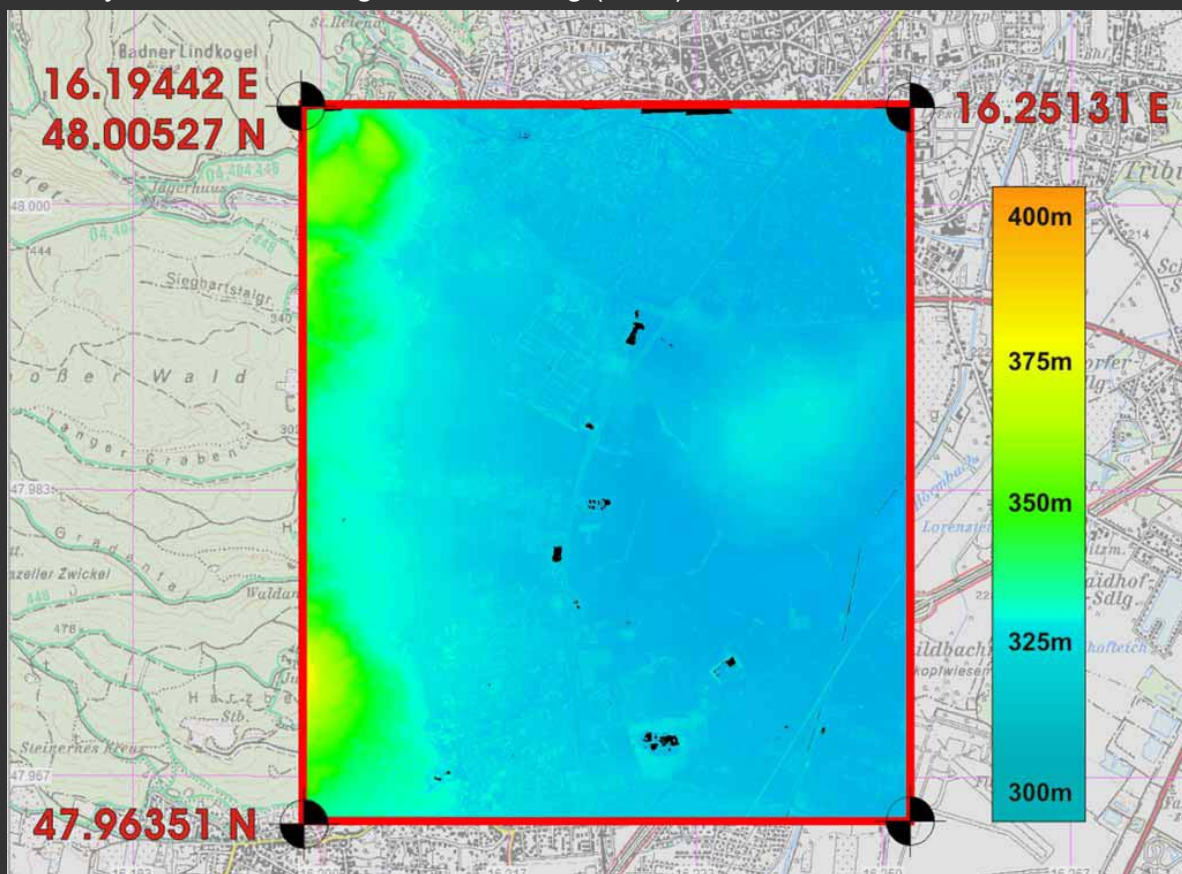
3D Punktwolke nach Entfernung von Echo Signalen  
mit großer Impulsbreite in ein Luftbild eingebildet



**RIEGL**  
LASER MEASUREMENT SYSTEMS

Runde Hügelgräber - Querschnitt

## Survey Evaluation – height color-coding (DSM)



Beispieldaten

### Turnkey Solution for Airborne Laser Scanning

aircraft	Diamond DA42 MPP	
air speed	40 m/s - 80 m/s	
laser scanner	RIEGL LMS-Q560, full waveform capabilities	
spatial density, 40 m/s (2 laser scanner)	AGL = 500 m	AGL = 800 m
@ 2 x 50 kHz PRR	3 meas / m <sup>2</sup>	1.8 meas / m <sup>2</sup>
@ 2 x 100 kHz PRR	6 meas / m <sup>2</sup>	3.6 meas / m <sup>2</sup>
@ 2 x 200 kHz PRR	12 meas / m <sup>2</sup>	7.2 meas / m <sup>2</sup>
storage capacity	> 8 hours of full waveform data recording	
ranging accuracy	2 cm	
geo-referenced accuracy	10 cm experimental data: less than 3 cm (1 $\sigma$ ) with reference objects, after post-processing	
approvals	certification category EASA part 23 (Europe), FAR23 (USA) , enables worldwide operation	



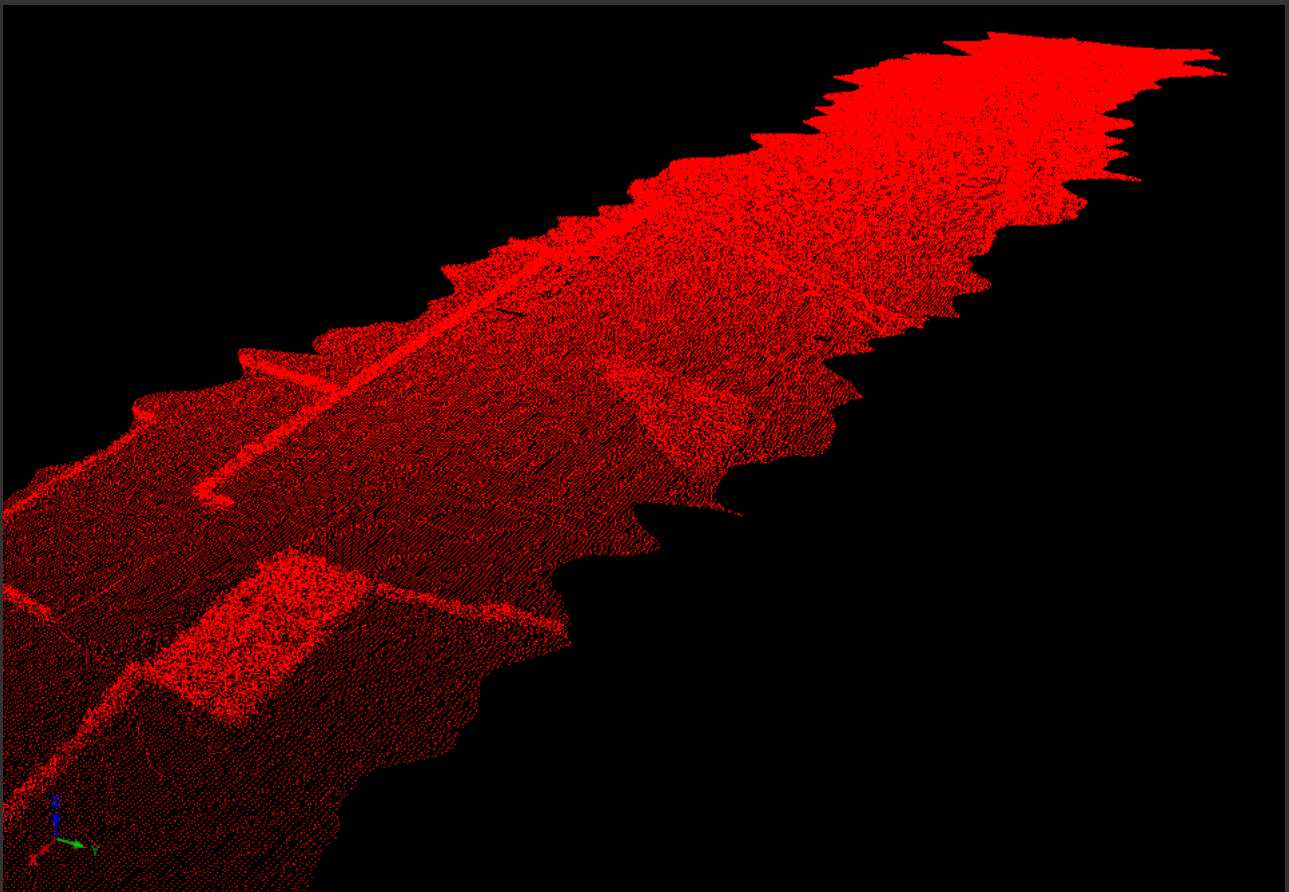
Spezifikation des ALS Gesamtsystems



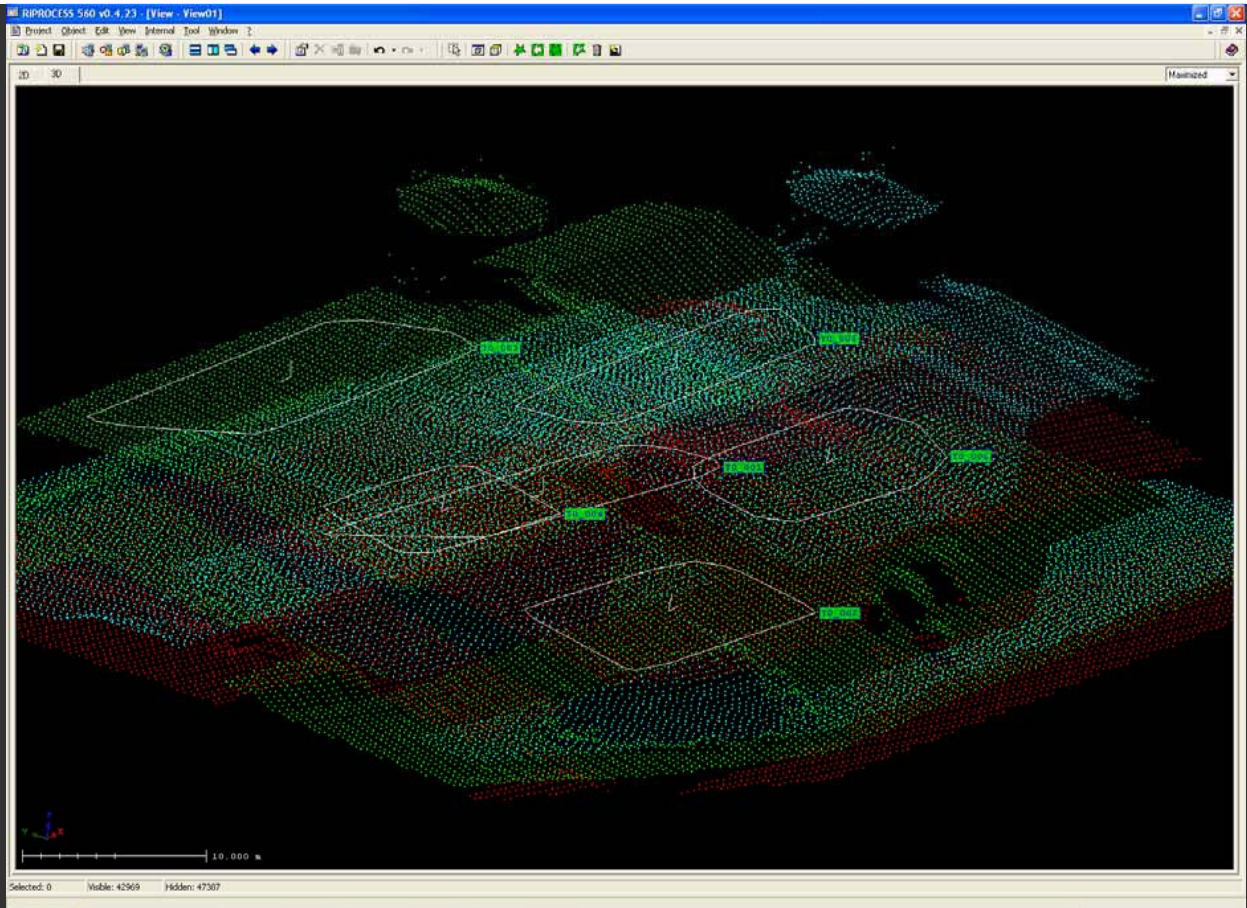
ALS & TLS Gesamtsystem (11. & 15. 1. 2007)



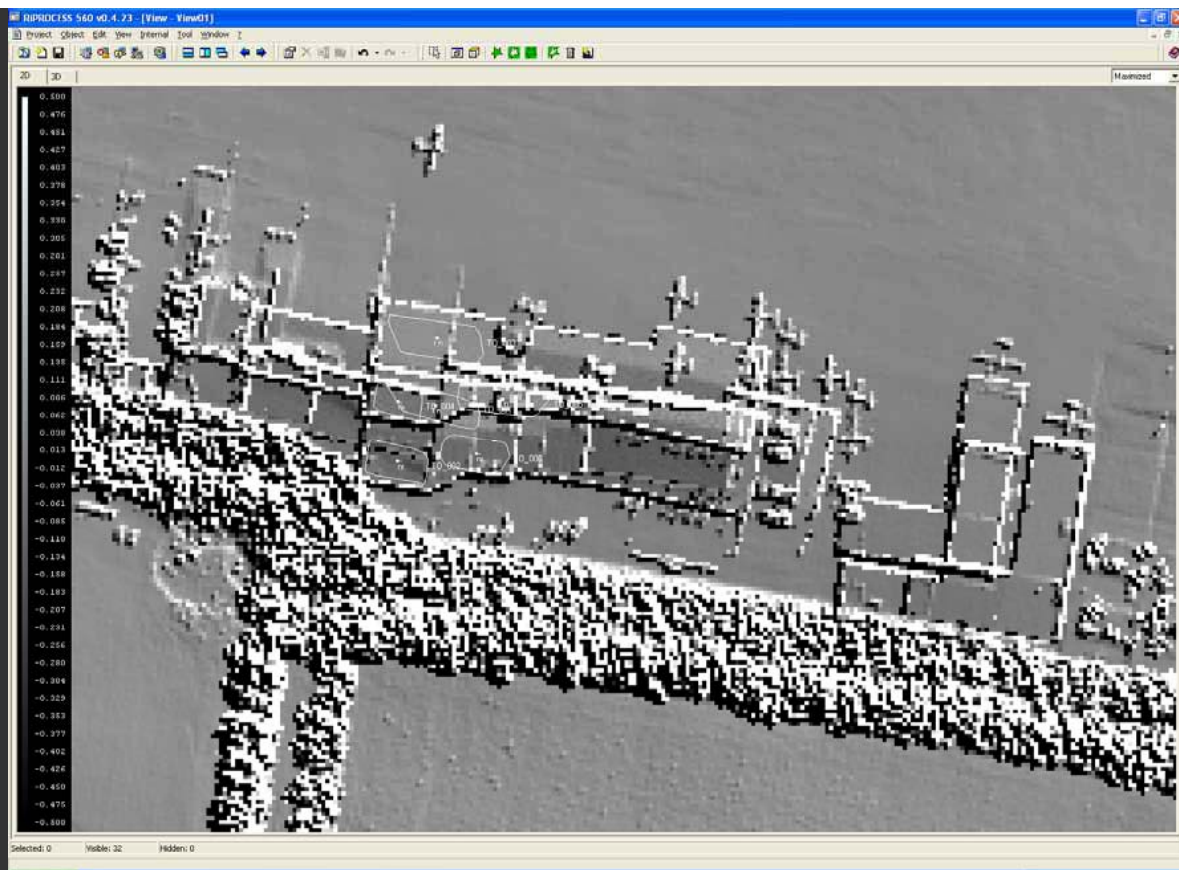
LOAG Flugplatz Krens Gneixendorf / Österreich



LOAG Flugplatz Krems Gneixendorf / Österreich



„Plane Patches“ vor dem Streifenausgleich, Punktwoken



„Plane Patches“ vor dem Streifenausgleich, schattierte Ansicht von oben

**Laser calibrations**

Roll	Pitch	Yaw
0.000	0.000	0.000

**ADJUSTMENT**

Number of free parameters: 0  
 Number of observations: 99  
 Error (Std. deviation) [m]: 6.1784

Create calibration files

Deviation [m]	Object 2	Deviation [m]
-15.637	070111_170457-TO_035	-15.637
-14.888	070111_171529-TO_028	-14.888
13.455	070111_171043-TO_028	13.455
12.906	070111_171043-TO_025	12.906
12.616	070111_171043-TO_015	12.616
12.132	070111_171529-TO_005	12.132
11.751	070111_170457-TO_025	11.751
11.377	070111_170457-TO_037	11.377
11.109	070111_170457-TO_033	11.109
10.701	070111_170457-TO_026	10.701
-10.562	070111_171043-TO_026	-10.562



Vor simultanem Streifenausgleich

**Laser calibrations**

	Roll	Pitch	Yaw	F
Scanner Vorne	-0.612	1.228	-0.070	

**Navigation calibration**

**ADJUSTMENT**

Number of free parameters: 3  
 Number of observations: 99  
 Error (Std. deviation) [m]: 0.0436

Create calibration files

**ADJUSTMENT**

Number of free parameters: 3  
 Number of observations: 99  
 Error (Std. deviation) [m]: 0.0436

Create calibration files

State: idle  
 Calculate Analyse Cancel  
 Undo last change Undo all changes  
 Apply changes  Reset

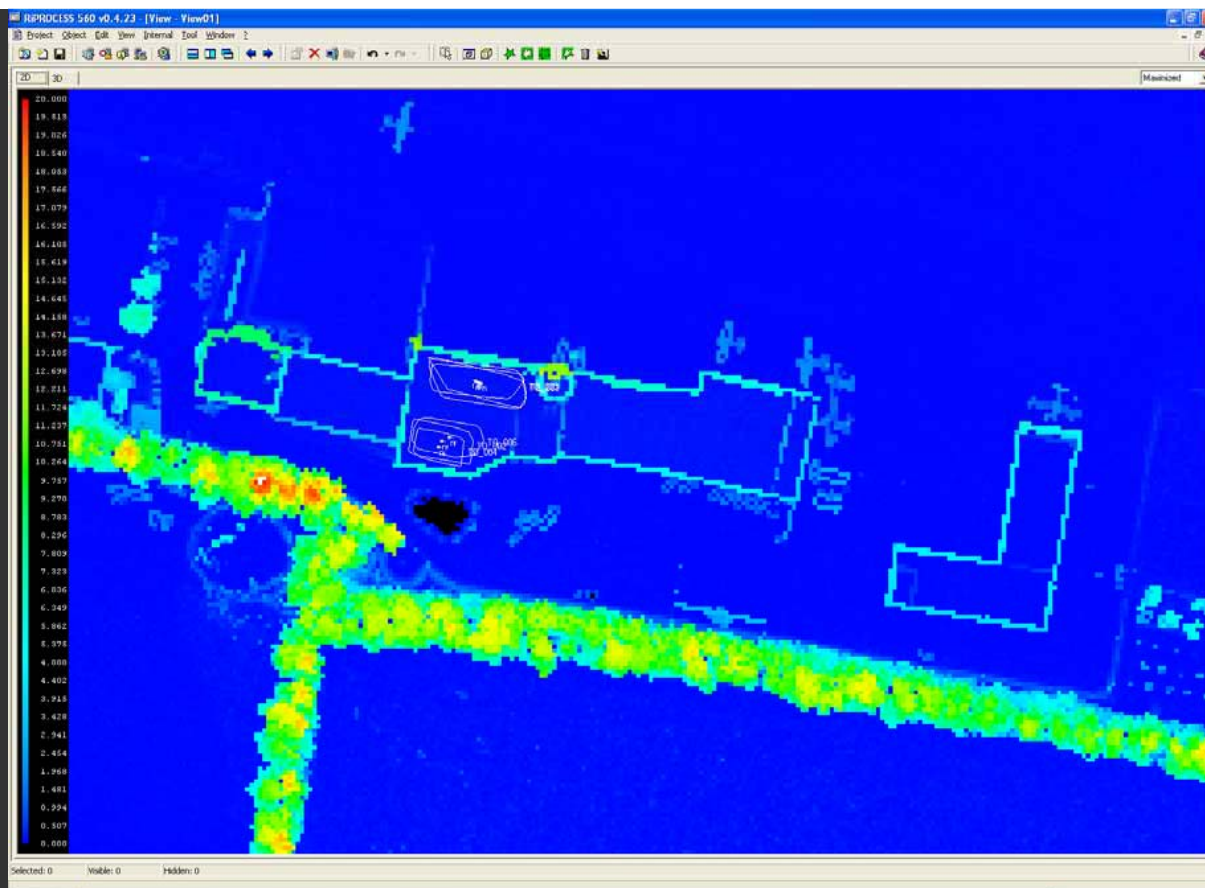
Object 2	Deviation [m]
TO_036	-0.155
TO_014	-0.109
TO_014	-0.095
TO_021	0.069
TO_026	0.069
TO_030	-0.069
TO_033	-0.065
TO_045	0.059
TO_011	-0.058
TO_014	-0.057
TO_021	0.057

Deviation [m]

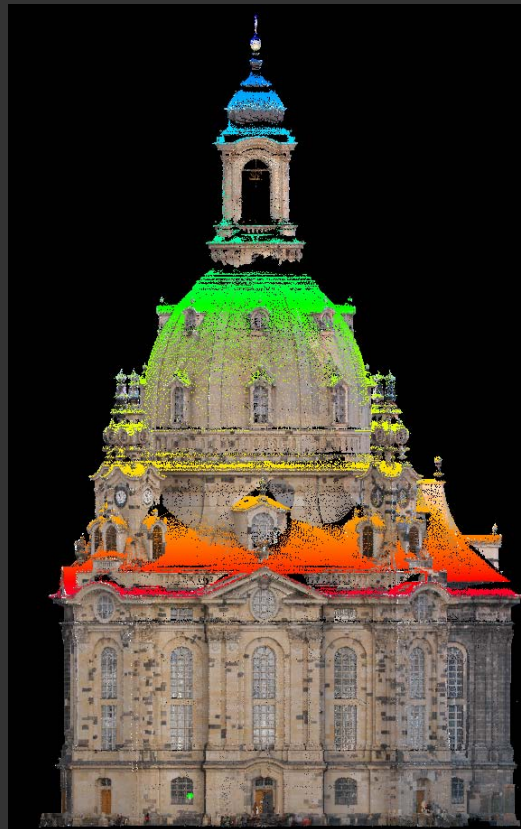
-0.155
-0.105
-0.095
0.069
0.069
-0.069
-0.065
0.059
-0.058
-0.057
0.057



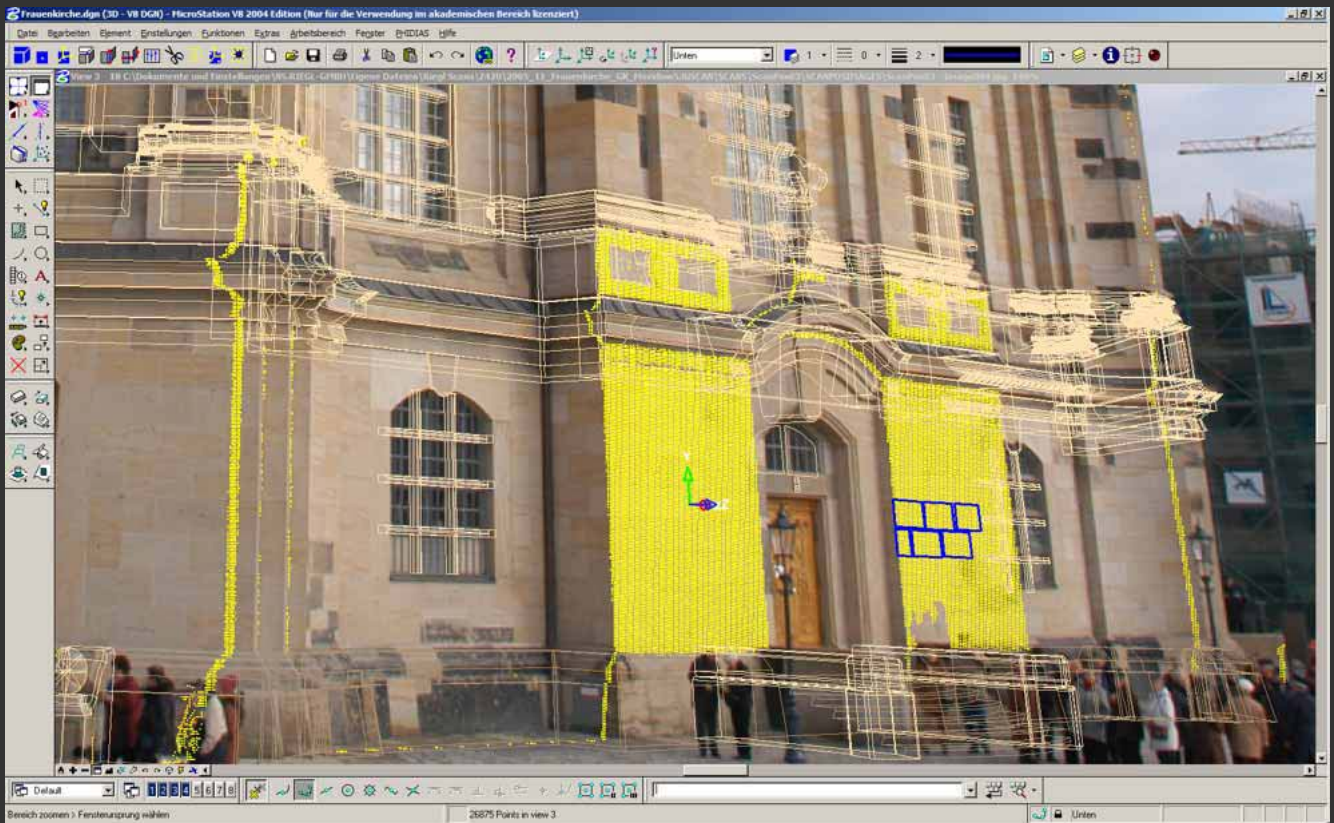
Nach simultanem Streifenausgleich und Einbaulage-Kalibrierung



Nach simultanem Streifenausgleich und Einbaulage-Kalibrierung



TLS (Echtfarbe) kombiniert mit ALS (farbkodiert)

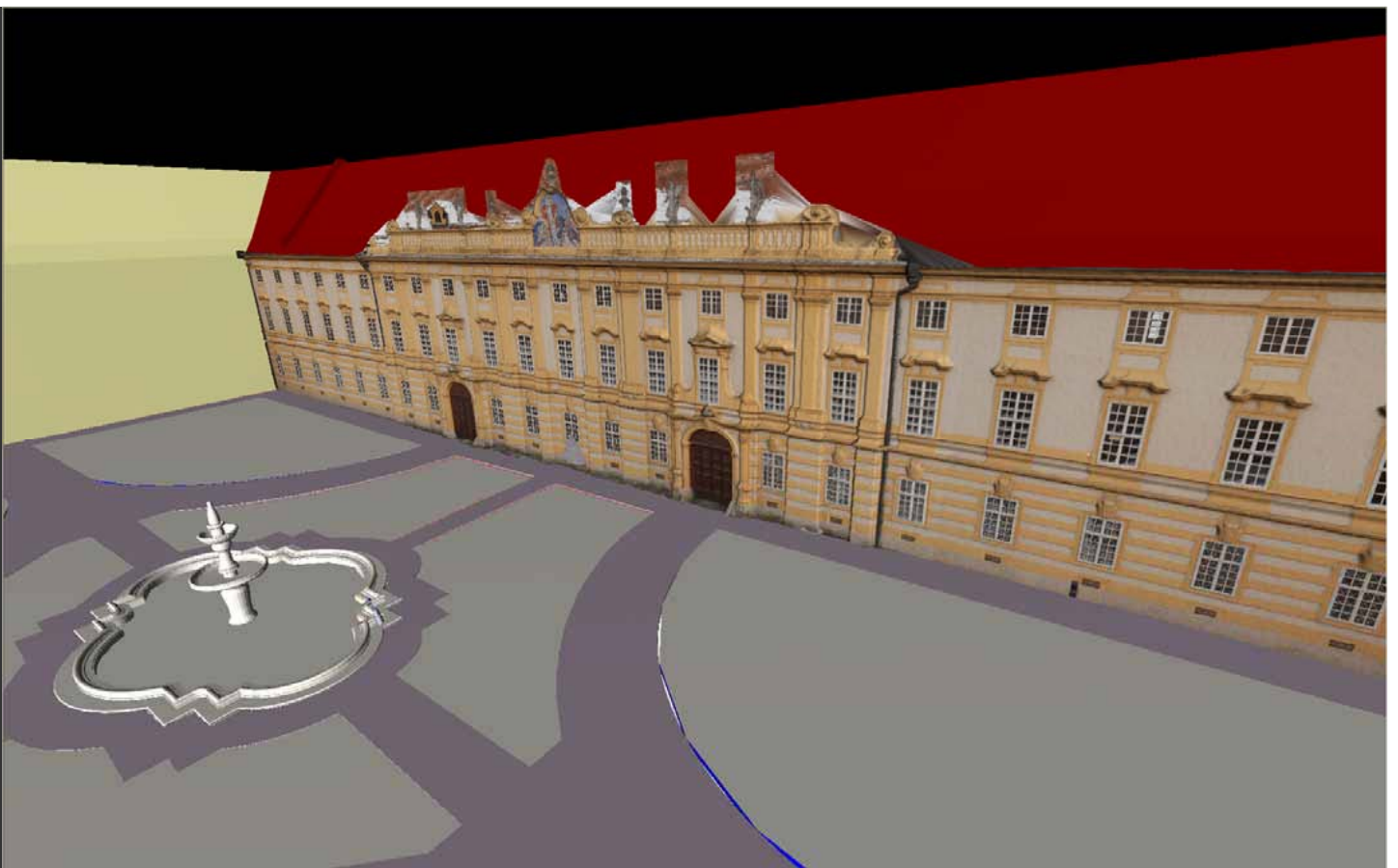


3D CAD Modellierung mithilfe von 3D Monoplotting (Phidias)





3D CAD Modell aus TLS und ALS Laser Scandaten



Beispiel TLS Scan – 3D Modell

# MLS 2D Laser Scanner Q240 am Boot (Frankreich)



MLS am Meßschiff (Hafen von Marseille)



GPS

2D Laser Scanner Q240

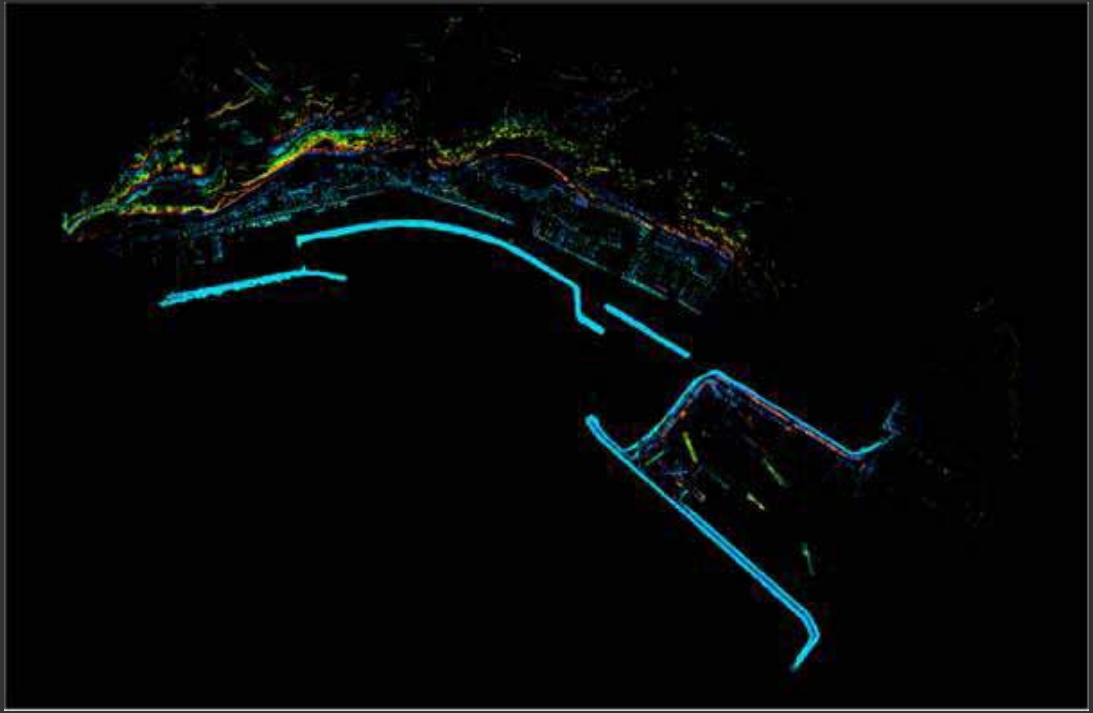
IMU IXSEA



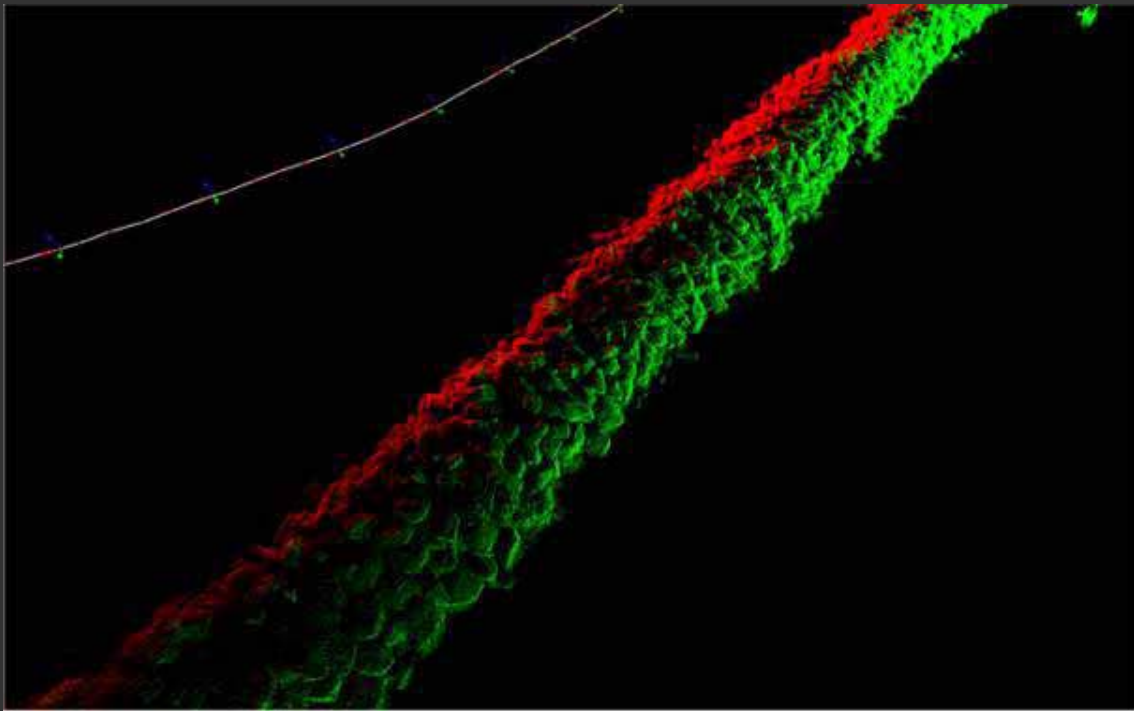
MLS am Meßschiff (Hafen von Marseille)



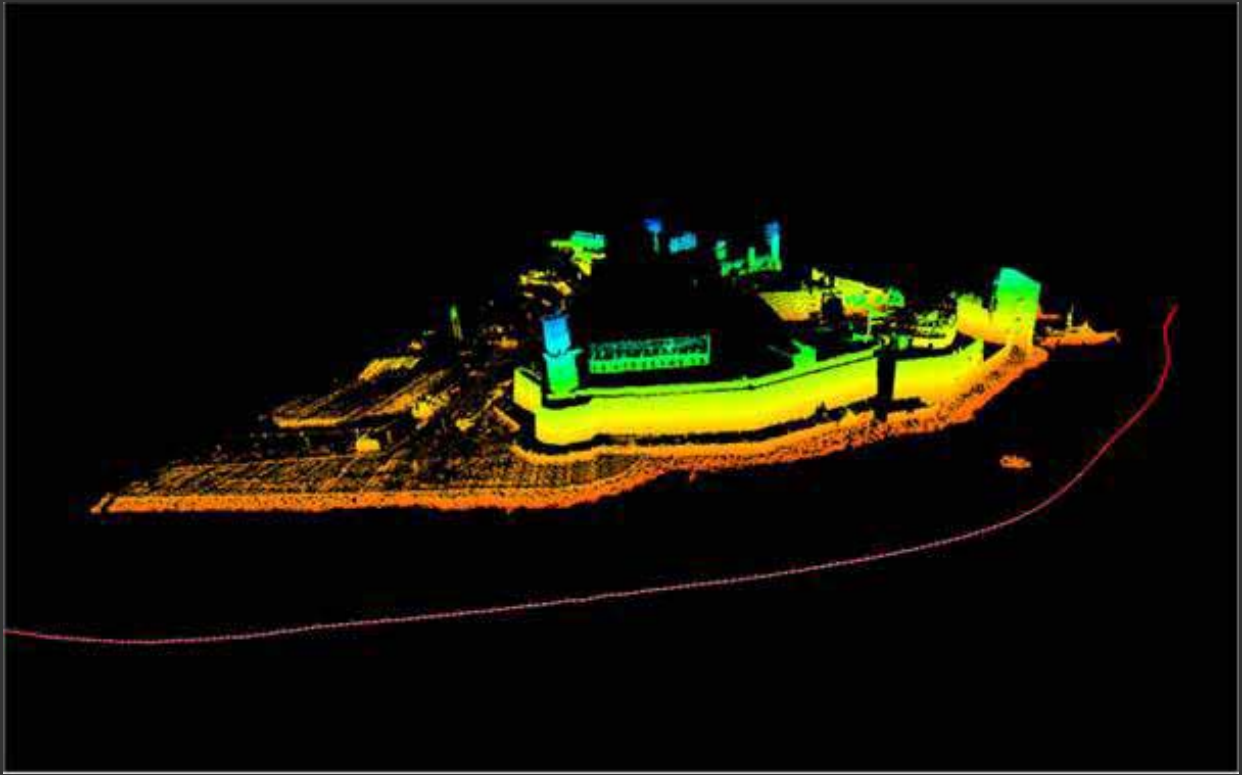
Google Earth: Hafen von Marseille



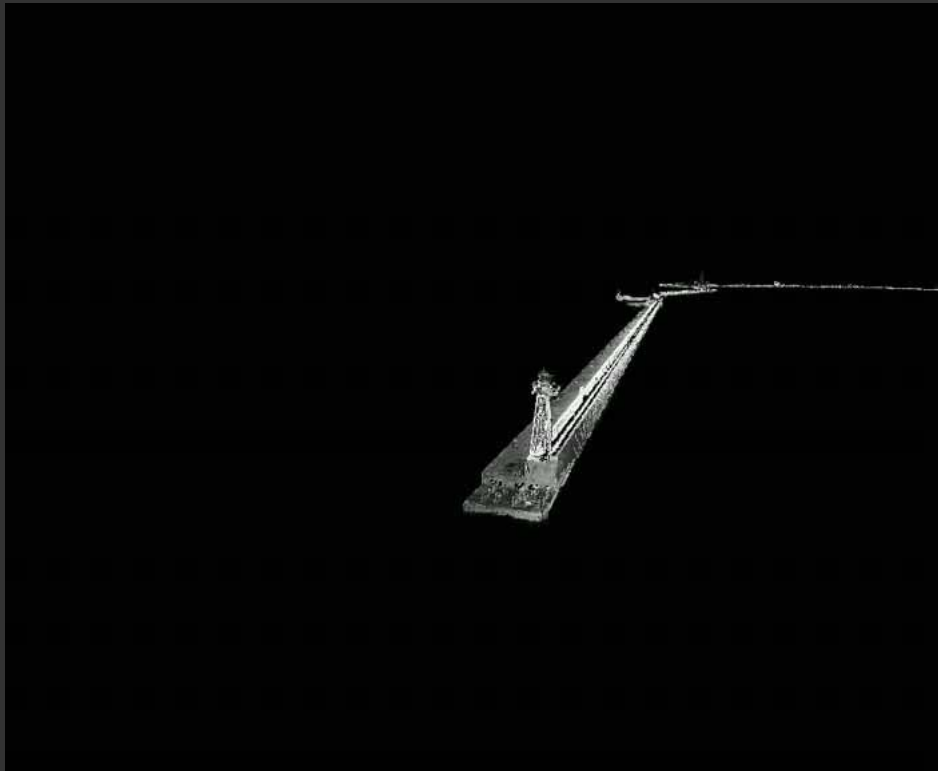
RiSCAN PRO: Hafen von Marseille



MLS Meßdaten mit Trajektorie des Meßschiffes



MLS Meßdaten mit Trajektorie des Meßschiffes



MLS Meßdaten

Vielen Dank für Ihre Aufmerksamkeit!

Herzlichen Dank für die Kooperation und Zusammenarbeit an  
Milan Flug GmbH [www.milan-flug.de](http://www.milan-flug.de) (Frauenkirche)  
Port of Marseille (Hafen von Marseille)

