Case Study

3D survey of the Cologne Cathedral.
The Blue Workflow – automatic real-time registration in the field.

Company Overview

Z+F is one of the world's leading manufacturers in the field of non-contact laser measurement technology. Due to years of research, development and numerous successful engineering projects, Z+F is the forerunner in this field with a wealth of knowledge, experience and success.

When it comes to implementing future developments Z+F has always encouraged innovative thinking and open-minds. Our loyal and long-standing customers appreciate our continual innovations, support and the services we provide.

In cooperation with Heriot Watt University Edinburgh and Fresenius University, Cologne.

The Cologne Cathedral

With about 157 m (515 ft), the Cologne Cathedral is the second highest church in the world behind the Ulm Cathedral. It is also one of the world's largest cathedrals in gothic architectural style. All elements of the late middle ages gothic architecture are realized in this building. The reason for this is the long construction period. The construction began in 1248. After 300 years, construction was stopped. The cathedral was completed in 1880. That's way the double front towers are neo-gothic architecture.

With 20,000 visitors a day, the cathedral is one of the most visited sights in Germany.

Since 1996 the Cologne Cathedral has been a UNESCO World Heritage Site.

The Cathedral in terms of numbers:

Height	157.38 m
Weight	160,000 t
Costs of the Cologne Cathedral – per day	30,000 Euro
Window surface	10,000 m²
Number of towers	11,000 Stück
Roof of the cathedral	2,300 m²
Weight of the Peters Bell	24 t - largest swinging bell in the world

A Sculpture of the Cologne Cathedral „Saint Anthony"

Objectives

Large numbers of visitors, air pollution, vandalism and natural aging processes damage the structure. Around the clock, 90 craftsmen of the cathedral workshop are busy with the preservation of the cathedral. In order to optimize the renovation work, the cathedral was surveyed three-dimensionally by using state-of-the-art technology. After the project the collected data should help to identify areas which need renovations and to plan the renovation jobs better. One special goal of the project was the high accuracy of the scans to detect smallest fissures, split-offs and breaks of towers, columns, arches, or statues for example.

Despite the size and complexity of the structure, another aim of the project was to scan the cathedral in its entirety from inside and outside. The project partners got 4 weeks to realise the project. The focus was particularly on areas which need renovations.

Damage of a tower

Damage of facade

Cooperation

Douglas Pritchard, a professor from the Heriot Watt University Edinburgh, has been dedicated digitalizing World Heritage Sites three-dimensionally for many years. He has already scanned Mount Rushmore and St Michaels Mount. On the initiative of Prof. Chris Wickenden (Academic Dean and Program Director of 3D-Design & Management at Fresenius University) the idea of 3D surveying the Cologne Cathedral was born.

At the beginning the cathedral workshop reacted reserved to the request of the two professors, because many universities have not been up to the surveying challenges of the cathedral before. However, Douglas Pritchard wasn't dissuaded from the project. He studied the plans of the cathedral in minute detail and planned every single project step. In this context, he also brought Zoller + Fröhlich into the project. Zoller + Fröhlich has been supporting non-profit projects in order to enable students practical experience for many years.

HOCHSCHULE FRESENIUS
UNIVERSITY OF APPLIED SCIENCES

HERIOT WATT UNIVERSITY

Equipment

During the whole surveying work, only 3D laser scanners from Zoller + Fröhlich were used. Due to the high stability, accuracy and speed, the devices are particularly suitable for this application. In combination with the integrated HDR camera of the Z+F IMAGER® 5010C and Z+F IMAGER® 5010X, materials, surfaces and shapes can be perfectly documented and displayed.

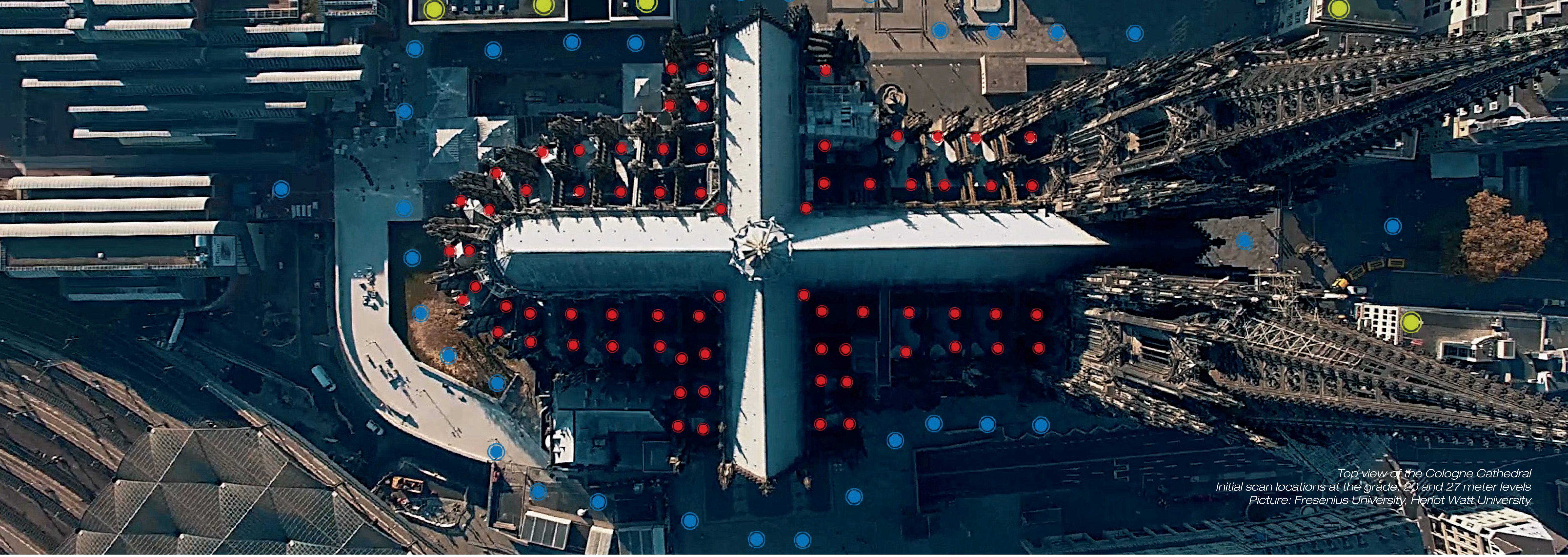
In addition, different scanner accessories were used.

The Z+F SmartLight was used for HDR images in dark environments. The external light, which can be easily mounted on the laser scanner, is extremely energy-saving so as not to impair the scanning time and has a working range of 1 m (3,28 ft) – 10 m (32,81 ft).

The T-Cam from Zoller + Fröhlich was used to detect not visible damage of the roof and insulation of the cathedral. With the external thermo camera temperature ranges between -20 ° C and 900 ° C can be documented in high resolution. The heat information will be automatically mapped to the 3D point clouds in post processing.

For areas which are difficult to access, overhead tripods, own tripod constructions, climbing equipment and lifting platforms were used.

Overhead tripod with the Z+F IMAGER® 5010X



Top view of the Cologne Cathedral
Initial scan locations at the grade, 20 and 27 meter levels
Picture: Fresenius University, Heriot Watt University

Project progress

The cathedral was scanned in two project steps. Each step took about two weeks. In the first step, the scanning work was focused on outside areas, especially on scanning positions from neighboring buildings and the ground.

The inside of the cathedral was scanned from different heights. Spider lifts were used, to take the laser scanners almost to the ceiling vault. The scanning positions, which were out of reach of the lifts, were attained by the triforium as well as the closing stone in the ceiling vault. The laser scanner was let down with an overhead tripod through an opening of the closing stone.

A small challenge was the large number of visitors. Due to the many people, there were many shadowings in the scans. This problem was fixed by additional scanning positions as well as blocking certain areas.

During the second project step, scans were done at different heights from the cathedral facade to capture the complex structure around the building.

Highlights were the scans from the two front towers at over 120 m. From the tower, the laser scanner was first faced to the ground to scan the roofs and towers. After that the laser scanner was faced to the top of the towers.

Z+F IMAGER® 5010X on a lifting platform at 35 m
Picture: Fresenius University

The evaluation and filtering of the scan data were done with Z+F LaserControl®. On the one hand the data was processed for technical applications and on the other hand for multimedia applications. That's why a lot of different software products were used in the post processing.

After 225 hours of work at the cathedral, 2 terabytes of data, 660 high-resolution scans and 360° HDR panoramas to color the scans, 6 billion points and more than 60 hours of film material, the project was a complete success for all project partners.

The whole project was documented with cameras by students of the 3D-Design & Management program. More than 60 hours of film material were produced, which were cut into a great documentary.

By entering the keyword „3D Laser Scan Cologne Cathedral“ you will find the video on YouTube.

Scanning at 120 m
Picture: Fresenius University

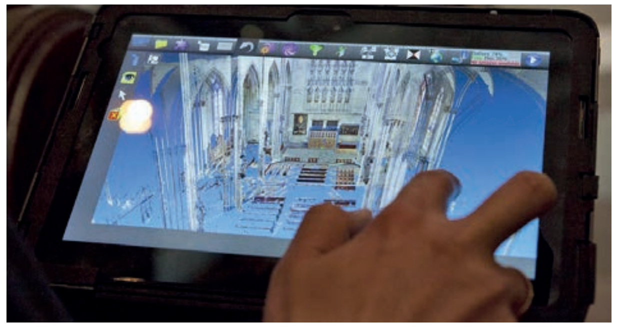
The Blue Workflow

The positioning system of the Z+F IMAGER® 5010X and the software Z+F LaserControl® Scout were used to keep an overview of the enormous amount of data and their quality.

The integrated positioning system helps to register point clouds fully automatically in real-time already in the field without using target's or other marks. This is made possible by a Cloud-to-Cloud algorithm, which uses the calculated position and orientation of the scanner as an approximation value to calculate the registration of the point clouds to each other. The Cloud-to-Cloud algorithm is contained in the registration software Z+F LaserControl® Scout. The software has been specially developed for Windows tablets and different applications in the field. Z+F LaserControl® Scout receives the necessary position information via WiFi to register the point clouds. After each scanning process, the scanner transfers the relevant data to the tablet.

Zoller + Fröhlich calls this registration process, supported by positioning system and the Cloud-to-Cloud algorithm, „Blue Workflow". The main advantage of this workflow is that the registration is already done in the field. This gives the user a better overview of the entire project, helps to recognize missing point clouds and scanning positions in the project. Because the registration takes place in the field parallel to the scanning work, it's possible to save time in the office.

Z+F IMAGER® 5010X



Z+F LaserControl® Scout HDR 3D Point Cloud View

Z+F LaserControl® Scout HDR Panorama View

Z+F LaserControl® Scout Scan Positions

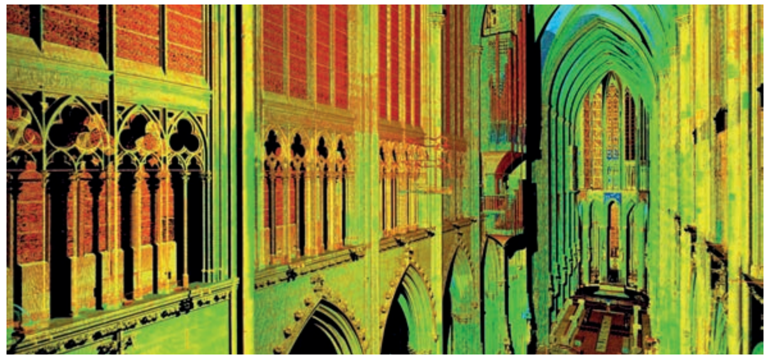
Colourized 3D point cloud of the transept
Picture: Heriot-Watt University

Results

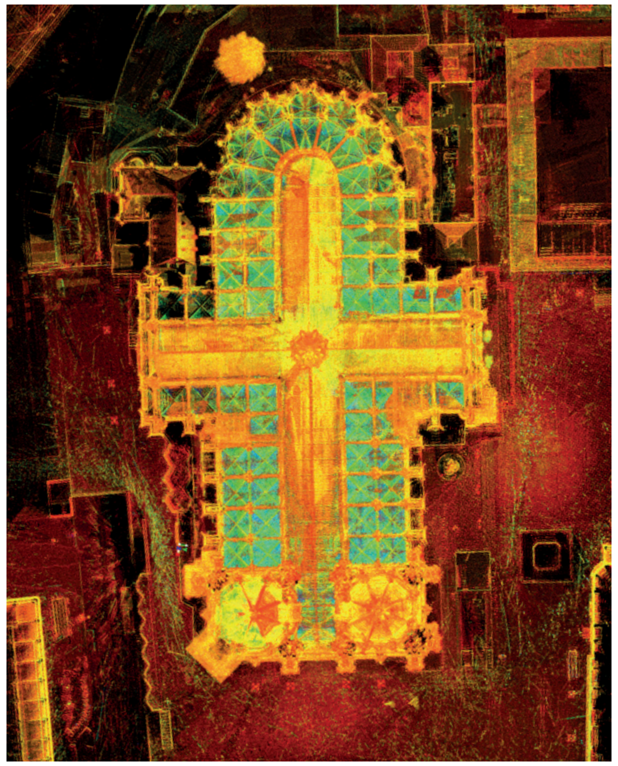
The Cologne Cathedral's surveying project was one of the largest study projects of its kind. The cathedral workshop has received a lot of important information by analysing the datasets. This information will be very important for the renovations in the next years to come.

Many students were able to get a great experience with of 3D surveying from a practical perspective during the project.

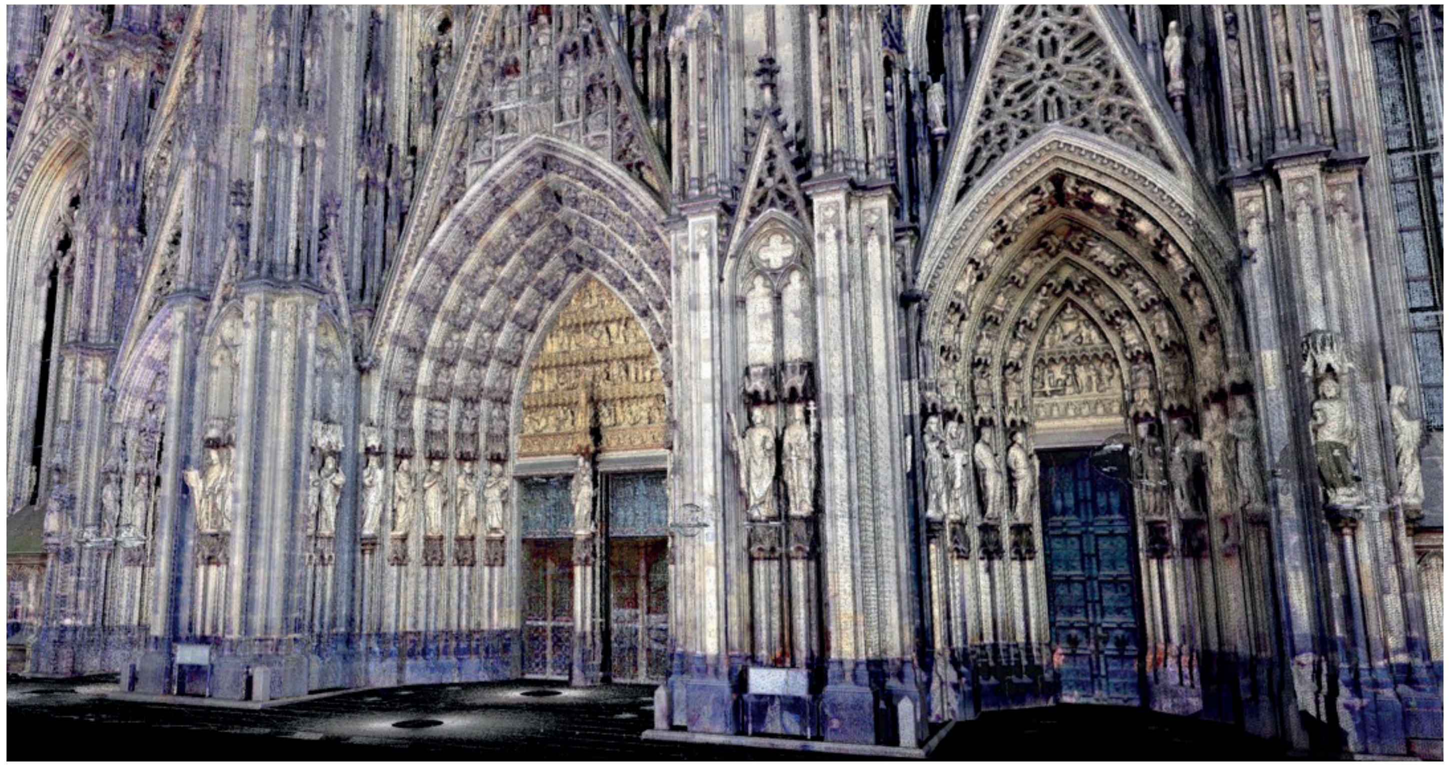
Also Zoller + Fröhlich had a lot of interesting experiences with this project and would like to thank all the project partners.



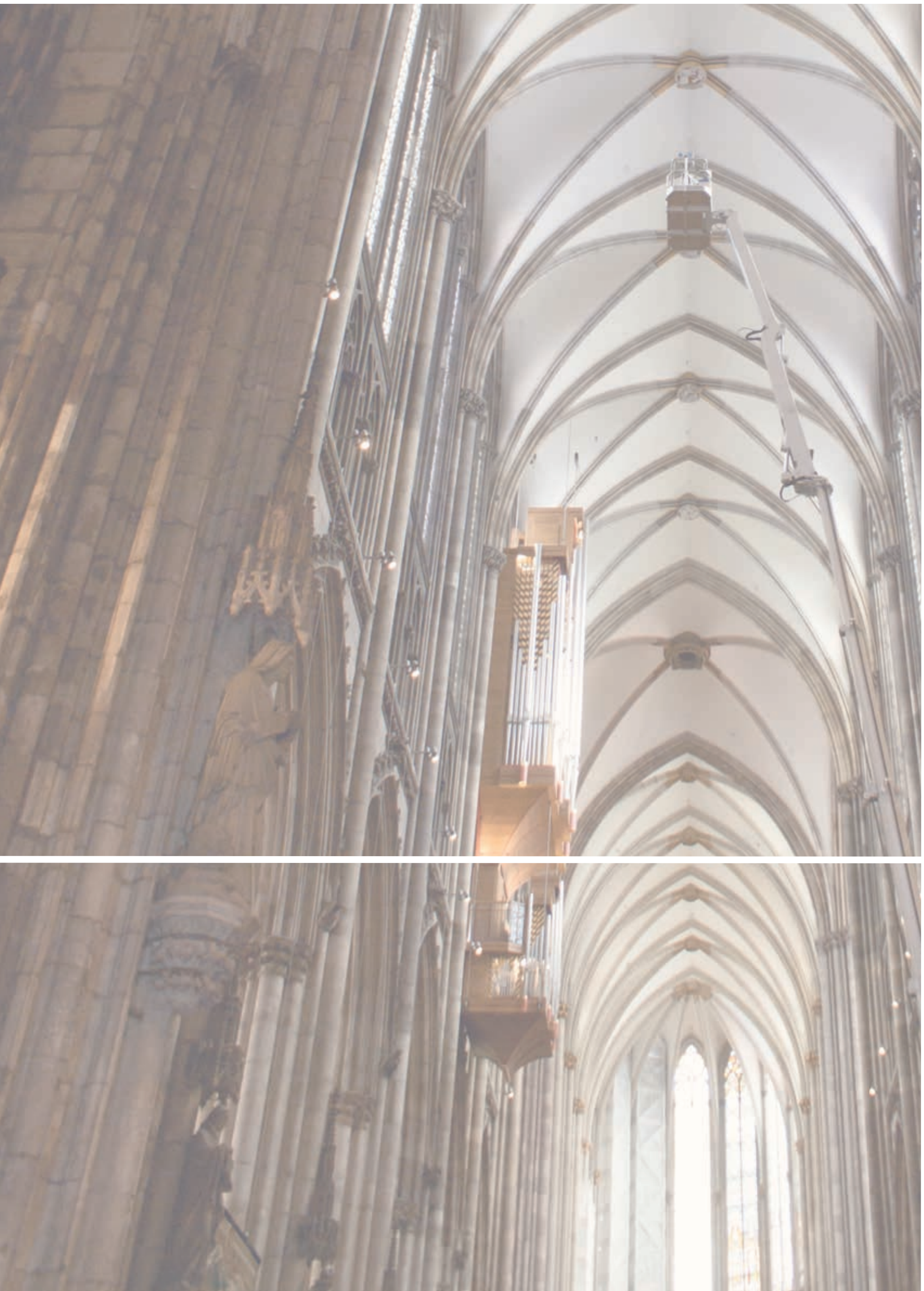
3D point cloud / nave
Picture: Heriot-Watt University



3D point cloud / top view of the Cologne Cathedral
Picture: Heriot-Watt University



Colourized 3D point cloud of the portal
Picture: Heriot-Watt University



Head office – Germany

Zoller + Fröhlich GmbH
Simoniusstrasse 22
88239 Wangen im Allgäu
Germany

Phone: +49 7522 9308-0
Fax: +49 7522 9308-252

www.zofre.de
info@zofre.de

Subsidiary – UK

ZF UK Laser Limited
9 Avocado Court
Commerce Way
Trafford Park
Manchester M17 1HW
Great Britain

Phone: +44 161 8717 050
Fax: +44 161 3125 063

www.zf-uk.com
info@zf-uk.com

Subsidiary – USA

Z+F USA, Inc.
700 Old Pond Road
Suite 606
Bridgeville, PA 15017
USA

Phone: +1 412 257 8575
Fax: +1 412 257 8576

www.zf-usa.com
info@zf-usa.com

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