Airborne city mapping
White paper

RealCity

PART OF HEXAGON

- when it has to be **right**

Leica Geosystems

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Leica RealCity
A new era of airborne city mapping

1. Complete solution for urban mapping professionals

Using a professional workflow solution as part of airborne mapping applications is as important as high-end sensor technology. In urban environments this becomes even more apparent. They are subject to rapid changes and thus have a higher need for up-to-date data for navigation, planning purposes and visualisation. In addition, oblique mapping projects over metropolitan areas generate large amounts of data that need to be processed within reasonable timelines. In order to meet the demands of mapping professionals requiring efficient data collection and fast data throughput without the loss of quality, Leica Geosystems has introduced Leica RealCity, a tightly integrated solution combining efficient imaging and LiDAR data collection using the Leica CityMapper with the high-performance post-processing workflow for high volume production Leica HxMap (Fig 1).

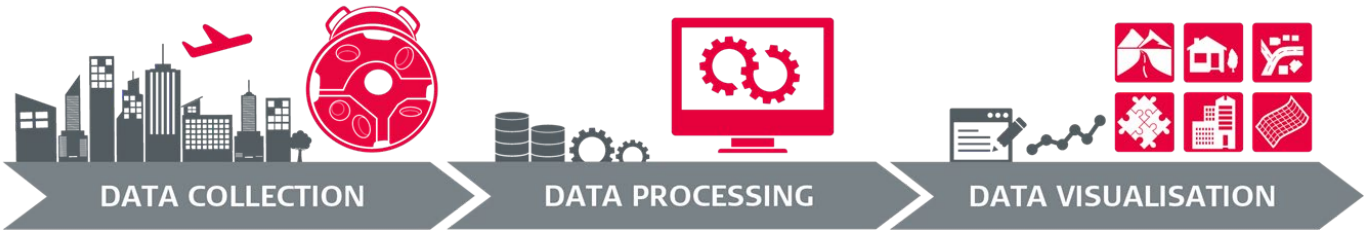

Figure 1: Leica RealCity end-to-end workflow solution for urban mapping professionals

2. From oblique to hybrid sensor technology

The majority of airborne urban mapping projects are currently flown with oblique cameras consisting of one nadir camera and 4 oblique cameras with an incidence angle of 45° in four directions (Fig 2). Such data is most widely used for basic inspection tasks, which often requires very little accuracy and thus minimal processing. Increasingly it is also used for automated building extraction, meshing and other 3D modelling, as well as for true ortho generation (also called 3D ortho). These products require higher accuracies for both nadir and oblique images and therefore more post-processing, including aerial triangulation of the entire nadir/oblique block as well as point cloud extraction using semi-global matching (SGM) algorithms over the entire block.

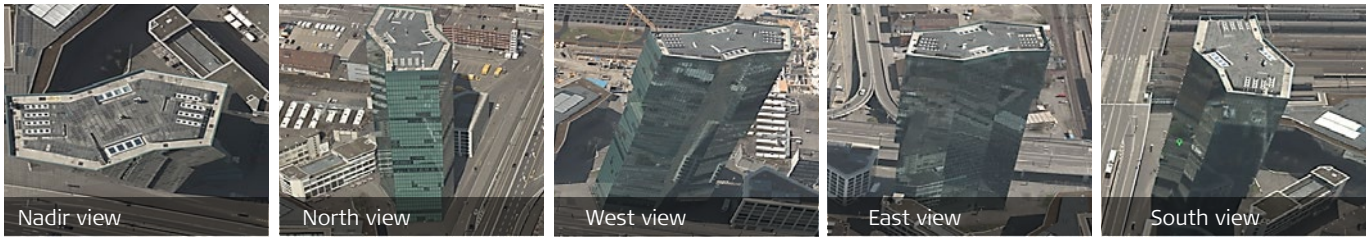

Figure 2: Nadir and oblique views generated from Leica RCD30 Oblique

In recent years, pixel based point cloud extractors such as SGM and dense matching in general have become essential parts of the imaging value chain as individual products or as intermediates for 3D value-added products. While this produces highly dense point clouds carrying a high level of information, image based point clouds are far from perfect and a number of effects negatively impact the quality of derivative products such as 3D buildings or meshes (Fig 3):

- Missing information through occlusions and canyons causes holes in the data
- Shadow areas usually carry a lot more visible noise, increasing the risk for mismatches
- The same applies to very homogenous surfaces such as parking lots (here the white lines can cause interesting effects) and water bodies
- And lastly vegetation, which can disturb results significantly. While multispectral cameras such as the Leica RCD30 help to improve results by being able to filter out vegetation, imaging technologies do not support views through the canopy at underlying objects, particulary lower portions of buildings and sidewalks or roadways under trees.

Particularly for meshed products, which are increasingly used for visualisation, these issues negatively impact quality through "meltdown" on building edges, poorly modelled vegetation and uneven surfaces.

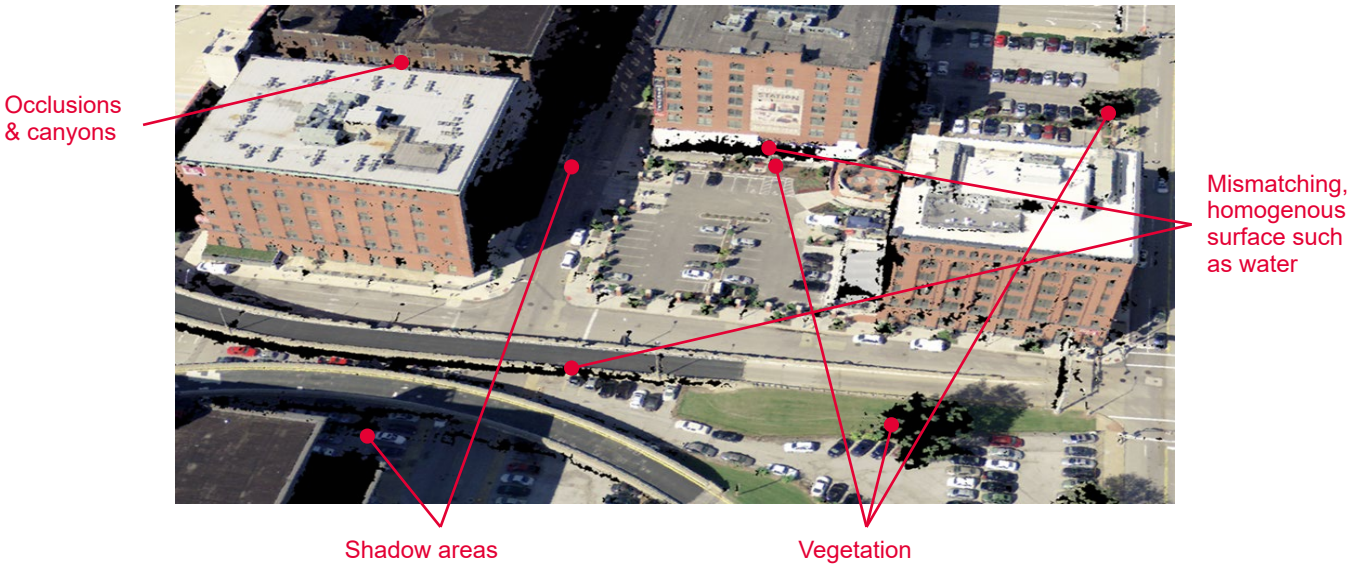

Figure 3: Possible problem areas of image-based point clouds

Looking at specific use cases and comparing the results of an image-generated point cloud with a point cloud generated from fused imaging and LiDAR data, the benefits are clear. In many countries up to 35% of urban areas are covered with trees. As such, an image-based point cloud is very dense on detailed surfaces like building facades and roofs. However, the digital elevation models of streets and surfaces under the trees are disturbed. This requires immense manual editing of city models, consuming a lot of time and resources. LiDAR penetrates through the trees and generates an accurate ground model with a flattened ground surface. In areas with shadows on the buildings or with irregular surfaces, the building edges in the image point cloud can be rounded or otherwise distorted. With the fused imaging and LiDAR workflow, these edges are much sharper and the models are more accurate (Fig 4).

IMAGE-BASED POINT CLOUD

LIDAR-BASED POINT CLOUD

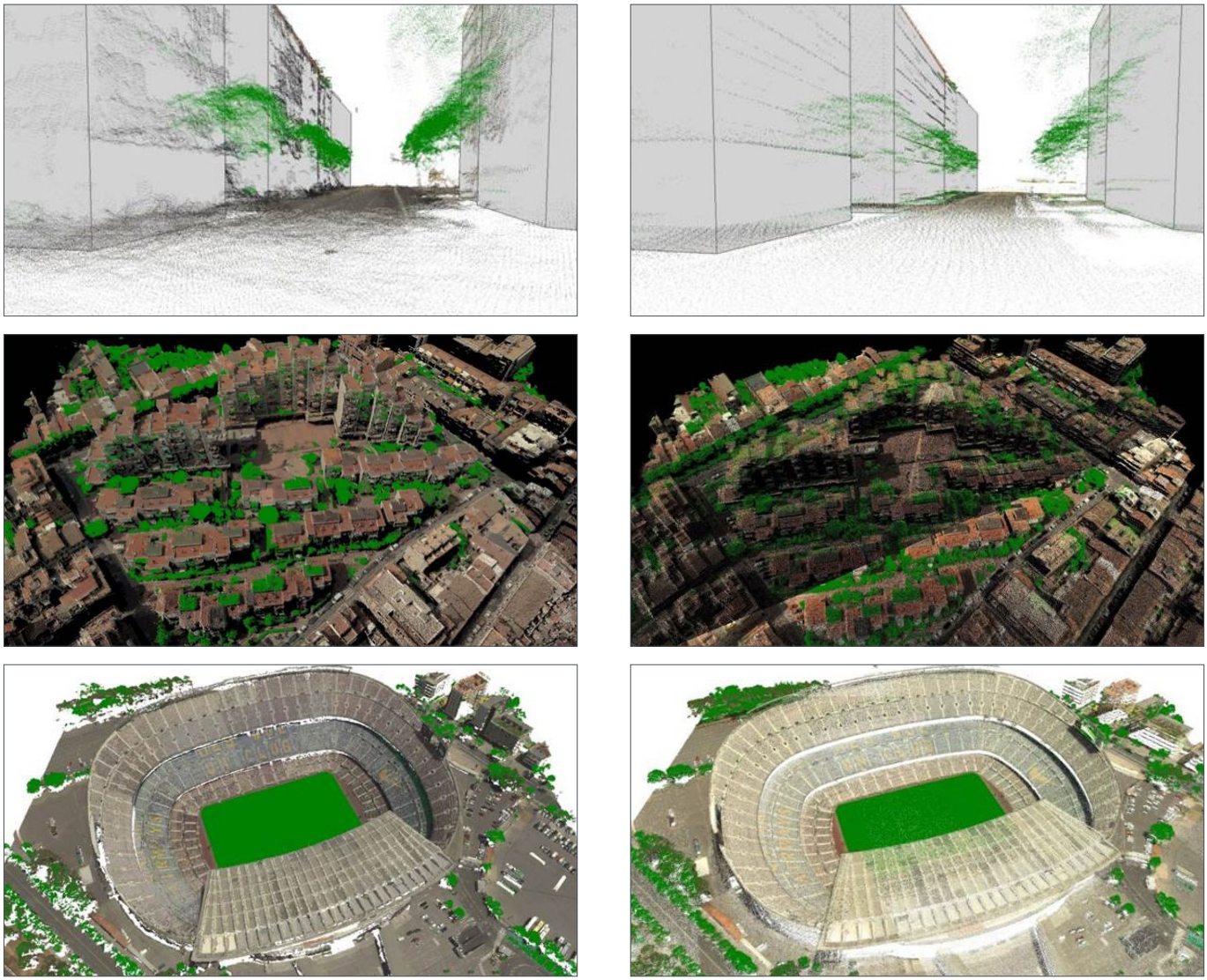

Figure 4: Point cloud derived from imagery (left) and LiDAR (right)

3. A natural next step

It is a natural next step to improve image based point clouds with LiDAR-based point clouds, adding accuracy and additional information to help create the best 3D model possible. As urban environments change rapidly, it is desired that image data and LiDAR data is collected at the same time, a requirement that gave birth to the Leica CityMapper (Fig 5), the world's first hybrid airborne sensor specifically designed for urban mapping applications. The simultaneous acquisition of nadir and oblique image data as well as LiDAR data offers the most cost-effective way to generate a comprehensive geospatial base map for city planners and those who are engaged in urban mapping: oblique images, ortho photos, DSM and DEM as well as derivative products out of the combined data set such 3D buildings and mesh (Fig 9, Fig 10). The fact that image and LiDAR data are acquired simultaneously minimises the possibility of discontinuities due to moving vehicles or other short-term changes in the urban environment, resulting in reduced data editing requirements.

4. Two sensor technologies in one pod

4.1. Leica CityMapper

Most survey aircraft have only one sensor installation port, therefore it was imperative that the five cameras and the LiDAR unit fit into a standard installation pod. This required a redesign of the proven RCD30 medium format camera as well as a completely new design for a LiDAR unit, the new Leica Hyperion.

The CityMapper contains an RCD30 CH82 multispectral (RGBN) camera in the nadir position. Four newly designed RCD30 CH81mini modules provide directional oblique views at a viewing angle of 45°. The new RCD30 design is much smaller yet maintains FMC to generate sharp RGB images in high resolution.

The new LiDAR unit (Fig 6) is based on an oblique scanner design with a large aperture, which has advantages for urban mapping applications. It supports a pulse repetition frequency of up to 700 kHz, 100 Hz scanner speed, a laser divergence of 0.25 mrad and can be operated an altitude of up to 2500 m AGL.

The 40° adjustable field of view is aligned to the nadir camera field of view and the circular oblique scan pattern provides a point density over streets, buildings and facades that will supplement point clouds generated from the images. In addition, other scan patterns can be generated. The LiDAR has an extremely high sensitivity, which allows the capture of even the smallest power lines and objects from a standard altitude of 1000 m AGL, with an average of 8 points per square meter. In addition, a new integrated 14-bit digitiser offers real-time waveform-to-range conversion with up to 15 return extraction. The interpulse separation is smaller than 50 cm. Full waveform data capture is available at down-sampled rates.

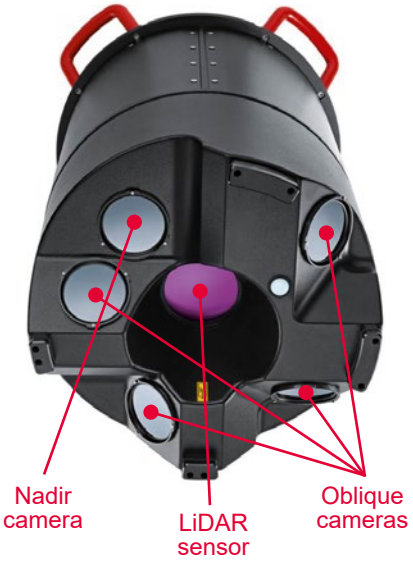

Figure 5: Leica CityMapper

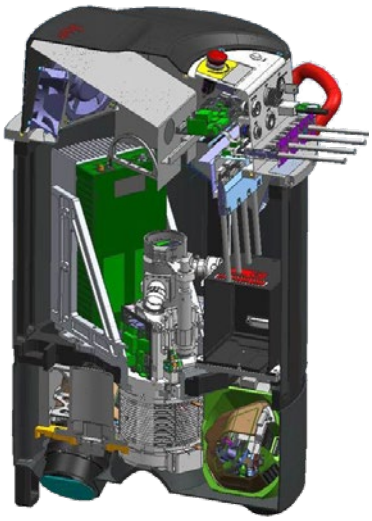

Figure 6: Leica Hyperion LiDAR system

4.2. A new sensor for the common sensor platform

Expanding on the common hardware concept, the CityMapper sensor head connects with the Leica CC33 camera controller collecting all data in one place. It is delivered with a Leica PAV100 Heavy Load gyro-stabilised sensor mount and a podlifter for easy installation and operation. All other peripherals such as the Leica OC60 operator console and the PD60 pilot display can be used with the CityMapper as well as any other sensor of the expansive Leica Geosystems airborne sensor portfolio (Fig 7).

Figure 7: Leica CityMapper system peripherals

5. High-performance multisensor post-processing workflow

5.1. Leica HxMap

Based on the proven production workflow Leica XPro, which is used for the Leica ADS sensor portfolio, HxMap employs the latest algorithms, visualisation and scalability tools that allow customers to process data from various types of sensors in the comfort of a highly efficient and user friendly processing environment. HxMap is the standard workflow platform for processing the output of Leica DMC III and RCD30 imaging sensors, as well as the complete array of hybrid sensor offerings, including SPL100, CityMapper and TerrainMapper. As such, it has developed into a unique platform to generate, visualise and analyse imagery and point clouds as well as their derivative products. Currently the available modules include the workflow manager, data QC, automated point matching, aerial triangulation, point cloud generation and orthophoto production (Fig 8). In addition, HxMap is designed around the HT Condor distributed processing environment, allowing users to respond to the higher data acquisition rates of today's advanced sensors, as well as to scale processing power to their data delivery turnaround requirements.

Customers who already own HxMap as part of another sensor system require an enabling license for the CityMapper as well as a LiDAR processing module, but maintain their existing imaging workflow configuration, making it easy to add and scale workflow production needs with a growing sensor fleet (Fig 8).

Leica Geosystems' leading 3D building model extractors City Modeller and Building Finder are now part of the HxMap, making it easy to generate value added products within the same environment and taking advantage of two complementing data sets, imagery and LiDAR, to generate higher quality products (Fig 9). A mesh option is also available (Fig 10).

Enabler Enabler, Workflow Manager	■
Provider Ingest, Raw QC	■
Core Image APM, AT, InfoCloud, Ortho Generator, Ortho Mosaic	■
Core LiDAR LiDAR calibration, Point cloud colourisation, LiDAR QC	◪
3D Modeller City Modeller, Texture Mapper, 3D Editor, Building Finder	■

■ = Standard ◪ = Recommended

Figure 8: Leica HxMap modules

Figure 9: 3D model generated over Barcelona from Leica CityMapper data

Figure 10: Mesh generated over Shanghai from Leica RCD30 Oblique data (courtesy of Pengtai, China)

6. Use Cases

The following case studies show how the CityMapper has been utilized in data collection.

6.1. Acquiring and processing LiDAR data across the US

Leica Geosystems partnered with international asset integrity and geo-intelligence solutions provider, Fugro, to begin acquiring and processing data over multiple cities and coastal regions across the US.

Using CityMapper, Fugro conducted aerial surveys over some of North America's most densely populated urban centres, in support of their geospatial mapping services. As the world's first hybrid airborne sensor combining oblique and nadir imaging as well as a LiDAR system into one instrument, the CityMapper enables significant time and cost savings by flying once to collect both imagery and LiDAR data. All collected LiDAR and imaging data can be processed in the one unified workflow solution, Leica HxMap.

Figure 11: Leica CityMapper oblique image of Stadium in Florida

"We have a long history working with Leica Geosystems sensors, because they are so reliable. CityMapper has proven no different," said Mike Wernau, Fugro program manager. "The platform's superior design, coupled with Leica Geosystems' newest version of HxMap, amplifies our ability to create highly accurate, feature-rich geospatial content."

The results of the airborne surveys were post-processed using the latest version of Leica HxMap, the unified high-performance multi-sensor workflow. Within a single and familiar interface common to processing other Leica Geosystems airborne sensors, all typical data products, from orthophotos and oblique images to point clouds, 3D meshes and models, can be quickly and efficiently produced.

The latest update of the common-sensor post-processing software sees the addition of LiDAR point cloud generation, calibration, strip matching and viewing to the current image processing capability. Leica HxMap also incorporates enhanced noise filtering for both CityMapper and Leica SPL100 single-photon LiDAR sensors.

"HxMap is extremely powerful, as it establishes a single environment to process our CityMapper oblique and nadir imagery, point cloud and terrain data all at once," said Wernau. "The products derived from the Leica RealCity workflow serve as the foundation for our land and property solutions, delivering real value to our customers in state and local government, insurance, and land-use management."

Figure 12: RGB and CIR image of Fort Myers Beach, Florida

6.2. Exciting CityMapper results in Bordeaux

The city of Bordeaux is among France's most exciting, vibrant and dynamic cities. It is a port city on the Garonne River in the Gironde department in southwestern France. Together with its suburbs, Bordeaux is the centre of the Bordeaux Métropole with about 760,000 inhabitants.

Bordeaux is the world's major wine industry capital. It is home to the world's main wine fair, Vinexpo and the wine economy in the metro area takes in 14.5 billion euros each year. After nearly a decade of infrastructure upgrades, Bordeaux was recognized by UNESCO as a World Heritage site for its vast Enlightenment-era urban core. After Paris, Bordeaux has the highest number of preserved historical buildings of any city in France.

Figure 13: Oblique view of Cathedrale in Bordeaux

APEI (Aéro Photo Europe Investigation), a well-recognised French aerial survey company specialising in the airborne acquisition of geospatial data using innovative techniques and equipment, worked together with the Direction de l'Information Géographique (D.I.G.) de Bordeaux Métropole for Bordeaux's city mapping project. APEI delivered aero triangulated obliques images captured with Leica CityMapper and Bordeaux will use these images to create a 3D city model.

D.I.G. de Bordeaux Métropole is responsible for managing the reference layers of the Geographic Information System used in the Bordeaux metropolis. The project was flown in only 2 days with a twin piston-engine Partenavia P68C, registered F-HPEI.

"The system uses Leica PAV100 and Leica FlightPro which are part of the Leica airborne common platform. It makes it really easy for our staff to operate and the training has been performed in only 2 hours. We used the Leica PodLifter which is specifically designed to lower the camera into the PAV100 to get full view for oblique capture. It was a very useful feature," said Bruno Callabat, CEO and technical manager, APEI.

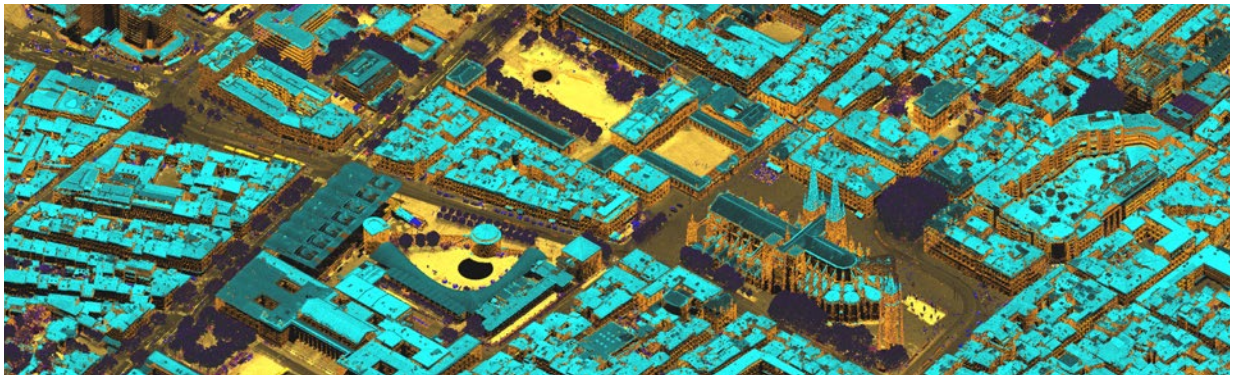

Figure 14: LiDAR class image capture with Leica CityMapper

7. Conclusion

Field use of CityMapper has proven (1) the viability of the hybrid sensor concept for city mapping applications, (2) the ease of adapting to CityMapper due to the Common Sensor Platform concept, and (3) the efficiency of a single workflow approach using HxMap. The simultaneous acquisition of nadir and oblique images along with LiDAR point clouds overcomes the limitations of earlier city modeling techniques using only point clouds generated from dense-matched images. Both building model accuracy as well as increased definition of ground contours in tree-covered or shadowed areas results from the addition of LiDAR data to the raw data stream. In addition, the simultaneous acquisition of the data results in less manual editing in order to filter out unwanted objects such as cars. The Common Sensor Platform results in minimal time to gain operational familiarity with the system, and the unified HxMap workflow allows all data to be loaded once and the entire workflow to be executed with minimal human interaction.

Figure 15: Bordeaux textured buildings

8. Availability

Leica CityMapper, as part of the RealCity solution, is currently available for delivery. Please contact your nearest sales representative for additional information or visit **www.leica-geosystems.com.**

Revolutionising the world of measurement and survey for nearly 200 years, Leica Geosystems creates complete solutions for professionals across the planet. Known for premium products and innovative solution development, professionals in a diverse mix of industries, such as surveying and engineering, safety and security, building and construction, and power and plant, trust Leica Geosystems to capture, analyse and present smart geospatial data. With the highest-quality instruments, sophisticated software and trusted services, Leica Geosystems delivers value every day to those shaping the future of our world.

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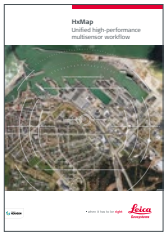
Leica RealCity
Airborne reality capture

Leica CityMapper
More information, smarter decisions



Leica HxMap
Unified high-performance multisensor workflow

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