ABSOLUTE ACCURACY IN THE ALPS

MARY JO WAGNER INVESTIGATES HOW INTEGRATING GNSS TECHNOLOGY, AERIAL IMAGERY, LIDAR DATA, MOBILE MAPPING TECHNOLOGY AND ADVANCED IMAGE PROCESSING SOFTWARE HAS ENABLED AN AUSTRIAN COMPANY TO CONDUCT DANGEROUS, MOUNTAIN MAPPING PROJECTS AND REAP THE REWARDS OF AN EXPANDED REVENUE STREAM

When a Cessna fixed-wing aircraft took off over an Austrian alpine region on an early morning day in August 2016, it ascended carrying two crew, a large format digital camera, a bit of uncertainty and a whole lot of risk.

The plane's mission was part of an overall project to provide a precise, as-built survey of a 40km, narrow stretch of railway in the Lower Inn Valley east of Innsbruck. Although this wasn't an unusual task for a surveying company, the required accuracy of the project was 2cm horizontal and vertical accuracy for the entire area of interest (AOI).

"For 2cm resolution, we'd have to fly about 500m above ground within a tight airspace," says Klaus Legat, head of the photogrammetry and aerial survey department at Vermessung AVT, a surveying company based in Imst, Austria. "We'd also need to supplement the aerial imagery with ground imagery, precise control points and software that could integrate all the data into an accurate, as-found map of the AOI."

This would be a test of whether modern surveying techniques could deliver such high accuracy over a large area. It was a risky proposition, but it proved a successful gamble.

Placing their bets

Located about 50km west of Innsbruck, the Alps are in AVT's backyard, making mapping and surveying mountainous environments a natural focus since the company's inception in 1970. As such, they've pushed their photogrammetric capabilities to the point where they routinely provide ground-resolution accuracies of 5cm or better.

The Lower Inn Valley (LIV) railway project would push them further.

A double-track high-speed main line of the Austrian Federal Railways (ÖBB), the LIV railway is a core part of the TransEuropean Transport Networks (TENT), a high-performance railway that will eventually connect southern Italy with northern Europe.

AVT's target was the 40km section between the Austrian towns of Kundl and Baumkirchen (KB), the first segment of the LIV that opened in November 2012. Designed for speeds up to 220km/h, the KB dual railway crosses the Alps and is the northern connection to the Brenner Base Tunnel, a 64km tunnel between Austria and Italy scheduled for operation in 2026.

In 2016, ÖBB Infrastruktur AG issued a tender for a final as-built measurement of the above-ground areas of the new line, the converted sections of the existing line and any objects within 100m of the tracks themselves. In addition to the 2cm vertical and horizontal accuracy requirement, ÖBB prohibited access to the tracks so a purely terrestrial measurement technique wouldn't be possible. There was also another complexity: the tracks were lined by up to 6m high noise-prevention walls.

The prevention walls and other obstacles would hide many along-track features from a plane's nadir-looking camera, so AVT chose to pair an aero photogrammetry survey with mobile mapping. The aerial data would give them the railway detail and the area outside the walls and the mobile mapper would supply the ancillary features not visible from the plane.

Critical to the multi-sensor approach, however, was the ability to integrate the diverse data formats into one image processing software to create precise orthophotos and a seamless orthomosaic. AVT selected Trimble's Inpho Suite to process its data, which offers

The peak of Rough Horn in the Tannheimer Mountains in the western Austrian state of Tyrol where AVT is based.

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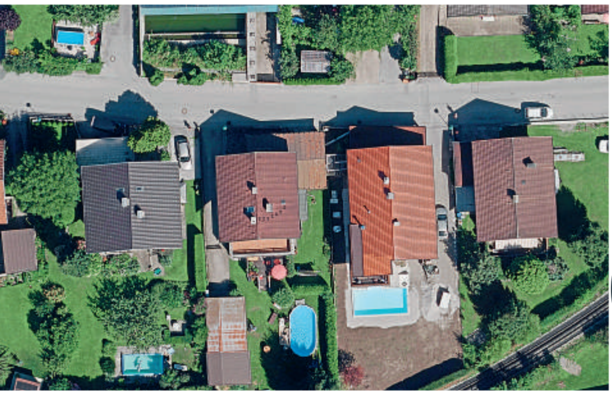
The Tyrol, where AVT is based © Kordi Vahle, Pixabay


The Kundl-Baumkirchen railway © Matt Tunjic, Pixabay


Right: The 40km Kundl-Baumkirchen railway section was the first segment of the LIV that opened in November 2012




The MXT captured a 30MP panoramic image every 4m along each of the tracks

photogrammetry modules for transforming aerial imagery into orthophoto mosaics, point clouds and other 3D datasets.

"Inpho can work with analogue and all brands of digital cameras," says Legat. "That flexibility and interoperability is quite important for us and saves us significant data processing time. It's also quite good at triangulating and multi-ray image matching which is the foundation for producing accurate results."

Rolling the dice

To achieve consistently high accuracy over such a long distance, AVT needed to first establish a precise control network and a network of ground control points (GCPs). Using two permanent base stations situated near the centre of the AOI, crews set out 30 GNSS receivers on predetermined locations and the units simultaneously collected measurements for 12 hours. The permanent survey established a base network precise to 0.5cm.

For the GCPs, teams painted markers on hard surfaces at 2km intervals around the 40km area and measured the centre points of each with shorter, static observations of about two hours. They set five points at a time and laid out a total of 50 GCPs with a horizontal accuracy of 1cm.

After setting control, AVT dispatched their flight crew to collect aerial imagery with a ground sample distance of 2cm. Flying at an altitude of 450m and an average speed of 200km/h, they covered the entire AOI in two hours. They flew 21 flight paths in an east-west direction and collected 1,300 images with their large-format digital camera. The images had a 60% overlap and the average lateral overlap between the flying segments was about 50%.

Per ÖBB's request, they also carried out a secondary aerial LiDAR mission to produce detailed point clouds to generate digital terrain and surface models. Reducing the altitude to 200m, a crew collected Lidar data with a point density of 25 points per square metre and a side overlap of 70%.

Completing the data collection campaign was a terrestrial survey using a Trimble MX7 mobile imaging system. The system was mounted on the roof of a small van that was placed on a wagon pulled by a special train. Maintaining an average driving speed of 50m/h, the MX7 captured a 30MP panoramic image every 4m along each of the KB tracks.

Into the ortho

After downloading and processing the aerial images and aircraft trajectory data, AVT personnel imported that data as well as the GCPs into the MatchAT georeferencing module of Inpho to automatically triangulate the images. Using an image pyramid process, the software analysed the 1,300 images and automatically pinpointed 15,500 common features or tie points (TPs) across the images, averaging 200 per image. The precisely surveyed GCPs were measured in the images and the MatchAT module used a bundle-block adjustment process to automatically and precisely orient the imagery. The accuracy of the GCPs in the AT was around 1cm in planimetry and altimetry.

With the OrthoMaster module, the software automatically orthorectified the individual images with a ground resolution of 2cm. Switching to Inpho OrthoVista each orthophoto was then stitched together to create a 2D orthomosaic for the whole AOI. Experienced AVT operators used the OrthoVista Seam Edit tool to manually check the seamlines to ensure they didn't cross objects like bridges which would be distorted in the mosaic. Any imperfections were fixed to create a seamless, colour-

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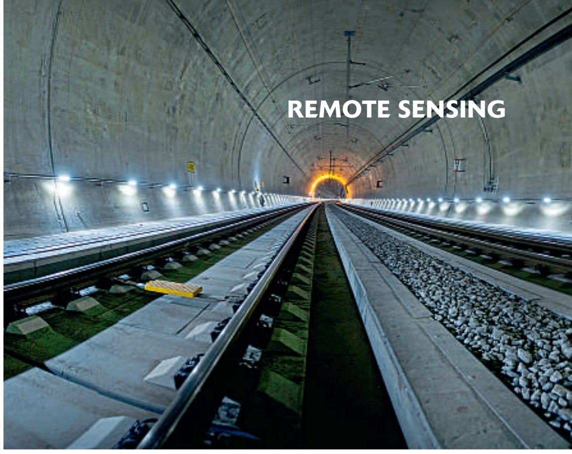
The Trimble MX7 mobile imaging system was mounted on the roof of a small van and pulled by a special train



balanced and geometrically correct orthomosaic of the 40km corridor.

AVT personnel used the Inpho interface to export the aerial images into DAT/EM Summit Evolution (DSE) software to create a 3D vector map of all railway-related features. The map was customised and finalised in AutoCAD.

In parallel with the aerial mapping, a team processed and precisely georeferenced the MX7 imagery to map objects that couldn't be seen in the aerial images. They first determined the path of the MX7 using the accurate GNSS/INS data recorded during the ride. They manually selected several hundred 3D points that had been determined as multi-ray TPs (aerial GCPs) within MatchAT, and used them to orient the MX7 images to ensure the maximum consistency between the aerial and mobile-mapping data.

They then extracted and mapped the mobile-mapping objects and exported the results to AutoCAD to produce the finalised 3D vector map showing the specific layers and symbols that had been defined by the ÖBB.

To process the aerial LiDAR data, personnel extracted approximately 300 horizontal surface sections from the data and determined the mean height and standard deviation per patch. They imported this data into MatchAT as vertical-only GCPs with a 2.5cm standard deviation. The ground points were used to process a digital terrain model and to derive height isolines, the latter of which were integrated into the 3D vector map.

Both the 2D orthomosaic and 3D vector map were delivered to the ÖBB in August 2017 and the authority conducted several independent evaluations to assess the quality and accuracy of the datasets. AVT's results were given full approval.

"This was such a satisfying achievement," says Legat. "We proved that with the right tools and approach, incredibly precise photogrammetry-based maps can be produced for the difficult alpine environment. More importantly, it has raised the profile of our multi-sensor fusion technique and given us the confidence to pursue similarly challenging projects."

After the survey

The successful proof of concept has piqued the interest of other organisations that service alpine communities. AVT is using the same flight data to support ÖBB's needs on the LIV railway and is scheduled to wrap up LIV-related projects very soon. And an Austrian electricity provider wants the company to map its electrical network at a horizontal and vertical accuracy similar to the KB railway.

But it's a safe bet that for the next high-precision mapping project, AVT's plane and its crews won't be carrying the same amount of uncertainty or risk.

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