Leica AP20 AutoPole: Advancing Productivity in Total Station Workflows **White Paper**

AP20 AutoPole

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Leica AP20 AutoPole: Advancing productivity in total station workflows

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1. SUMMARY

Automated total stations are common tools of choice for land management and construction applications as their continuously improving sensor capabilities and software applications support precise, fast, and frequent geospatial data acquisition. However, similar advances to the surveying and construction pole, an integral component to the process, have remained absent over the last decades.

Leica Geosystems' latest pole-side innovation addresses this problem by extending reliable sensors onto the surveying pole. The result is a smart solution that allows measurements with an arbitrary tilted pole, automatic detection and recording of pole height changes in the field software, and total station search and lock only to the intended target. This paper introduces the Leica AP20 AutoPole, describes the three distinct functionalities enabling increased productivity, and reviews measurable improvements to the overall workflow.

2. INTRODUCTION

Accurate geospatial information is essential for land management, infrastructure development and maintenance, building construction, and more. While complex projects requiring spatial data are growing, a shortage of skilled workforce to acquire it highlights the need for automation across processes. Therefore, methods for fast, simple, and frequent data acquisition that integrate easily into measurement workflows are crucial.

Total stations help address these challenges with automated features enabled by continuously progressing sensor capabilities and software applications. However, the survey pole has not made similar strides towards automation, leaving an integral component of the automated workflow a manual process.

Some of the pain points regarding time pressure, safety, and quality assurance when measuring with total stations include:

- Slowed productivity with manual levelling effort and limited accessibility where the pole cannot be held vertically.
- Potential for errors when manually entering the pole height, with no possibility for digital traceability.
- Distracted pole operators who cannot fully focus on the measurement task, causing potential safety risks.
- Slowed initial setup and interference with prism locking on busy sites with multiple crews and targets.

Figure 1: The Leica AP20 AutoPole is a unique and productivity boosting smart solution for survey and stakeout work with Leica Geosystems automated Total Stations.

To overcome the described challenges, Leica Geosystems developed the Leica AP20 AutoPole. This pole-side innovation complements Leica Geosystems' automated total stations and extends reliable sensors onto the surveying and construction pole to addresses major problems across survey and layout workflows.

The first-of-its-kind development of an IMU-based tilt compensation for Leica Geosystems' GS18 T Smart Antenna was a primary factor leading to the creation of the AP20. The GS18 T overcame the levelling constraint of GNSS poles and provided a proven technology suitable for integration into the total station environment. Merging this capability with other concepts to automatically detect height changes of the pole and eliminate manual searches, the AP20 was developed as a comprehensive solution.

The technological convergence in the AP20 addresses core pain points by making it possible to:

- Measure with an arbitrary tilted pole, speeding up work and increasing access to points
- Automatically detect and record height changes of the pole in the field software
- Eliminate manual searches by making it possible for the total station to search and lock only to the intended target.

The AP20 works with both Leica Captivate and Leica iCON field software, seamlessly integrating into the overall measurement workflow and enabling the total station and surveying pole to become an interconnected solution which increases flexibility and productivity.

Industry Applications

Across the following construction and survey measurement tasks, the Leica AP20 AutoPole enables greater flexibility, safety and productivity.

- Topographic surveys in areas of natural obstacles and urban barriers
- Layout work on busy construction sites with multiple crews
- Road surveys in high traffic areas
- Measure utility and infrastructure which is difficult or dangerous to access
- Precise and traceable as-built survey

3. TILT COMPENSATION

User challenges with manual levelling

Levelling reflector poles for every point measurement causes a variety of problems for operators, ranging from losses in productivity to safety concerns to a lack of trust from missing traceability of the manual levelling quality. Conventional reflector poles require the survey engineer and layout engineer to put emphasis on precisely levelling the pole before each point measurement, which takes time and concentration.

For topographic surveys with hundreds of points captured over a day, a considerable amount of time is spent on manual levelling. In the case of mechanical, electrical and plumbing (MEP) work, layout engineers can get frustrated and slowed down when dealing with complex design data and doing several layout steps for each point simultaneously.

Additionally, the necessity of an upright pole alignment restricts accessibility to points of interest, such as manholes obstructed by a parked car, points behind trees blocking line of sight to the total station, or points in trenches. These restrictions often lead to time-consuming workarounds requiring extra accessories, like tape measures to apply manual point offsets, or moving the total station to a new setup location.

Quality control is also problematic with manual levelling. Even the highest-grade, accurate total stations cannot prevent coordinate errors caused by mistakes when levelling the pole. Like other tools, analogue bubbles are not error-free, and they only reach their specified accuracy when properly and regularly adjusted. Additionally, a survey engineer who is post-processing the captured data in the office cannot know how well the pole was levelled for each single measurement in the field.

3.1 IMU-based Tilt Compensation

The AP20's tilt compensation functionality allows operators to disregard the analogue bubble to survey and layout points with an arbitrary aligned pole. This increases productivity in the field and allows nearby hidden measurements which were previously cumbersome to capture.

The whole measurement chain is based on reliable sensor input instead of manual levelling constraints. IMU technology is used within the AP20 to determine the 3D pole alignment in space. Similar to the Leica GS18 T (Luo et al., 2018), an IMU based on industrial grade, microelectron-mechanical systems (MEMS) include a three-axis accelerometer and a three-axis gyroscope to precisely measure acceleration and angular velocity.

These observations, together with continuous target positions from the total station, are provided to a customised inertial navigation system (INS) integrated into the AP20. The INS algorithm mathematically rotates and integrates the IMU measurements into the coordinate system of the total station and determines the attitude of the pole and its associated quality measure (Maar, 2022).

Figure 2: Forget the bubble and increase productivity by measuring points with an arbitrary aligned pole.

Figure 3: Stake points with highest accuracy in reversed tilt mode by using a small target height.

Initialising the AP20

To measure with Tilt Compensation, the AP20 needs to be initialised by an arbitrary pole movement of several seconds (Leica Geosystems, 2022). The most effective way to do this is as follows:

- Make large enough movements in varying directions to derive valuable accelerations from the IMU.
- Move with moderate speed so that the total station can keep tracking the prism.
- Maintain the movement a few more seconds so that the initialisation can be strengthened.

For more information on initialising the AP20, watch the online learning video.

3.2 Accuracy

Individual measuring tasks require both quality, reliability, and traceability. Survey engineers and construction surveyors need to know on-site if the current point quality is suitable for their needs. Further, office applications require the possibility to trace back the accuracy grade of the captured data to allow quality control and post-processing. In addition to productivity loss, the manual levelling process using an analogue bubble highly restricts these desired capabilities.

The AP20 fills this gap of a seamless and digital dataflow through reliable sensor use. With a comfortable pole handling within 15° tilt, the AutoPole typically allows the same or better performance levels than when trying to precisely level. In contrast to manual levelling, the amount of tilt and its equivalent point quality is stored with the data for each point.

Highest precision, usually only achievable with static pole configurations like a bipod or spider, can now also be reached in reversed tilt mode by simply holding the prism closer to the point of interest.

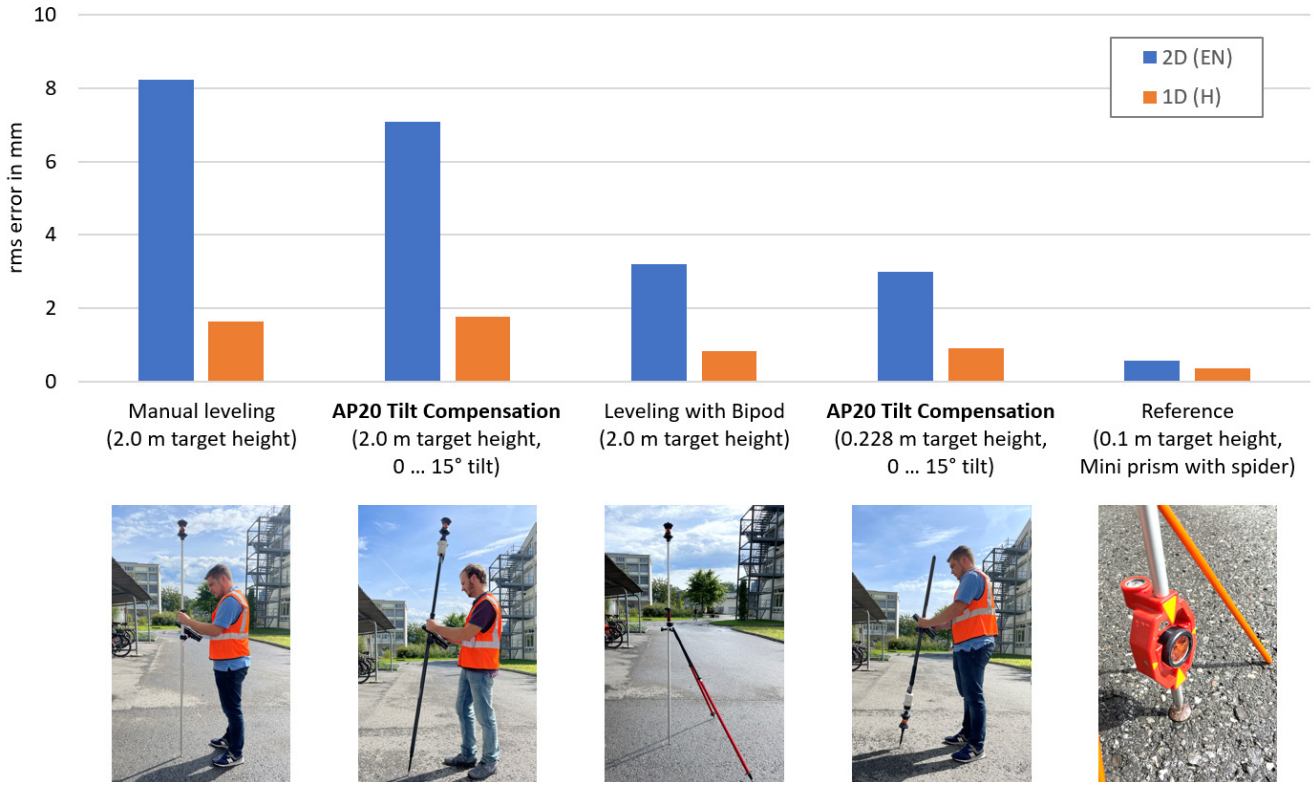

Figure 4: Root mean square (rms) error of pole tip position using different pole configurations. Each bar is based on a dataset of > 200 single point measurements on GRZ122 prism (resp. GMP111, for reference), captured by 4 different pole operators to obtain an average levelling skill and using a 1" total station at 100 m

3.3 Benefits of Tilt Compensation

By providing tilt compensated measurement in real-time, operators save time with every single point they capture. Previously inaccessible points, such as behind or below obstacles, can now directly be measured without offset calculation or additional time-consuming total station setup. The operator can focus on the surroundings and the actual survey tasks instead of being distracted by the analogue bubble. This provides more comfort and safety, especially on construction sites or near roads.

Research and operator tests have shown up to 50% productivity boosts through increased effective measurement time with the AP20. Evaluations by Eder (2022) demonstrated that for a typical surveying job with a variety of measurement and stakeout tasks, the AP20 saved over 2 hours each day. Additionally, surveyors from Swiss company Käppeli Digital AG reported a 50% increase in speed across surveying tasks when tested on a pipeline installation and road construction project ("Innovative Surveying Technology," 2022).

Stakeout tasks can be sped up even more by directly moving the pole tip to the desired design location according to the guidance of the Leica Captivate field software, instead of iteratively repeating the steps of moving the prism, leveling the pole, and checking guidance values.

The operational benefits of the AP20's tilt compensation have the interconnected effect of improving productivity, accuracy, and safety for survey engineers and construction surveyors across their on-site tasks and overall workflows.

Figure 5: Speed up work using Tilt Compensation and simultaneously increase the operator's safety at challenging site conditions.

4. POLEHEIGHT

Challenges delivering correct height data

Survey engineers and construction surveyors need to deliver data with correct heights. While an extendable pole helps overcome line-of-sight interruptions, the resulting process of changing the height repeatedly includes many steps and can result in errors.

For example, new heights:

- Need to be read from the printed height scale on the pole, leaving the possibility that the new height can be misread and typed incorrectly into the field software.
- Must be communicated to the total station operator for 2-person operations, leaving room for miscommunication between colleagues and incorrect data entry.
- Needs to be entered into the field software, which can be completely forgotten due to distractions on site.

The consequence is a high potential for incorrect heights within the captured data. Additionally, when measuring with a tilt compensated pole, the overall 3D coordinate would be calculated incorrectly. Updating the data to reflect correct target heights is possible if the correct heights can be remembered.

However, tracing back the actual target height and updating all affected measurements requires significant effort in post-processing or a return to the field for re-measurement.

4.1 Magnet-based snap lock detection and update

The AP20's PoleHeight functionality eliminates the effort and risks of these manual steps. A physical extension or reduction is automatically detected by the pole and communicated to the field software of the connected total station or field controller. Within the field software, the target height input field is updated accordingly. Therefore, apart from extending the pole to the desired height, no further action is needed from the operator.

The technology consists of several parts. Starting from the supported Leica AP reflector poles, the handgrip on the lower tube includes a built-in magnet inside the pin which snaps into the individual snap lock positions of the upper extendable tube. This upper tube on the other side contains passive electronic components. Hall sensors behind each snap lock position detect the nearby magnetic field coming from the magnet at the handgrip and can therefore assess which position is currently snapped in.

Pole dimensions and order of hall sensors behind the snap lock positions are known and, as a result, each detected position can be referenced to its height value if the pole is engaged into a snap lock position. Near-field communication (NFC) is used to transmit the read height from the pole to the attached AP20, which forwards the update to the connected field software on the total station or field controller. Based on inductive coupling, the NFC technology provides data exchange and allows the pole to harvest energy from the attached AP20. This means, the pole itself does not require any internal power source.

When an intermediate position between two snap-locks is set, none of the hall sensors will reply to a magnetic field and based on that, the pole will state an invalid height reading. The field software then informs the user to manually enter the intermediate height.

4.2 Benefits of automatic height readings

The PoleHeight feature brings reliability and time savings benefits, giving pole operators the flexibility to change heights when needed while ensuring correct values are entered into the software when snap lock positions are used or providing reminders when manual entries are required.

This significantly reduces the risk of incorrect target heights and therefore avoids later correction or re-capture of the data. At the same time, using the combination of PoleHeight with the Tilt Compensation functionality reduces the need for intermediate, manual heights since the pole can instead be tilted towards a free line of sight to the total station.

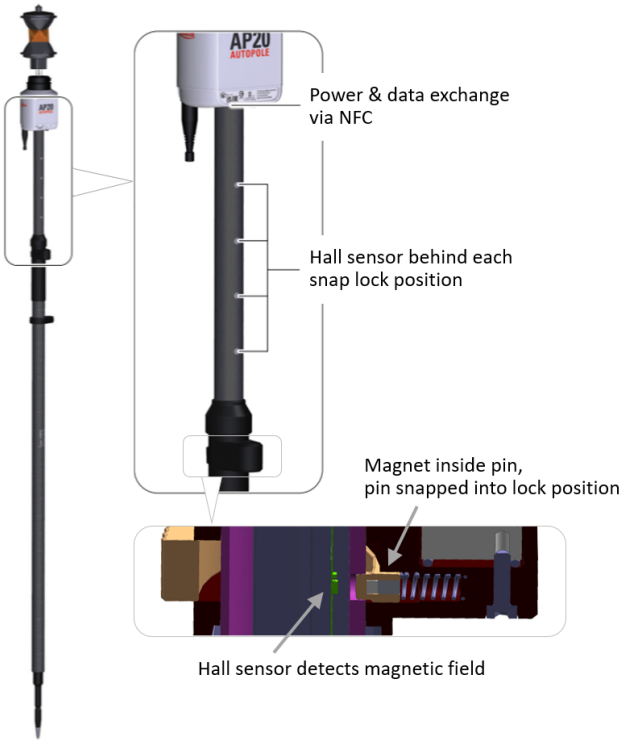

Figure 6: Schematic view of relevant components to detect the current height.

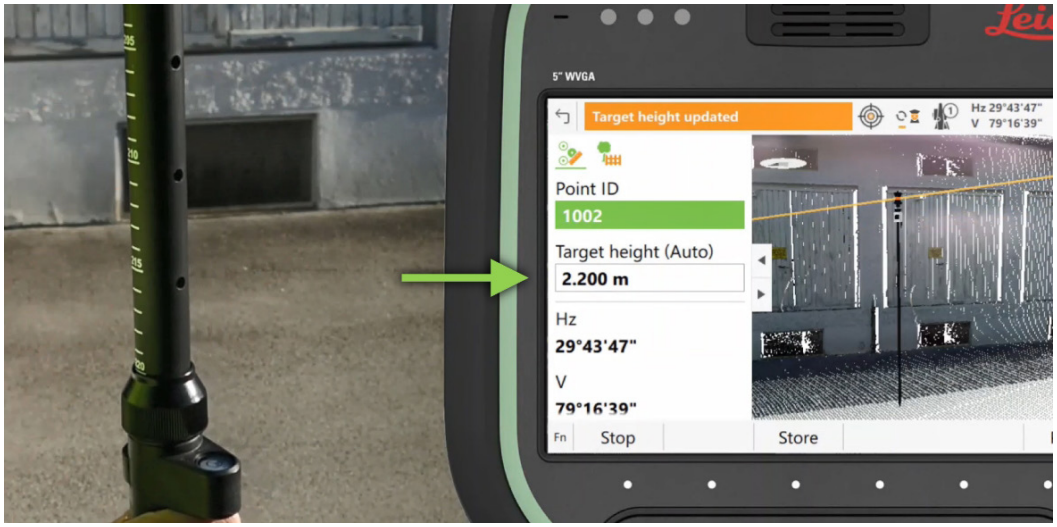

Figure 7: Height changes of the pole are automatically and immediately updated within the field software, eliminating the risk of wrong target heights.

5. TARGETID

Target identification challenges on busy sites

Tight time schedules put significant pressure on surveying and construction professionals that need to execute tasks correctly and on time. This becomes even more challenging on busy construction sites, with different crews working in the same area using their own surveying equipment – such as total stations and reflector poles – for their individual tasks. For data capture and layout tasks, this can lead to disturbances in the initial target search and later through line-of-sight interruptions.

Repeated search-find-verify steps take time, and the more targets, the longer it can take. In particular when working in 1-person operation remotely from the field controller on the pole, it can be difficult for the operator to verify on which target the total station is currently aiming.

This all leads to distraction from the workflow, frustration and increased downtime, where no survey tasks can be performed. Productivity suffers and scheduled construction phases can be at risk to be delayed.

5.1 PowerSearch-based target identification

The AP20's TargetID functionality enables an automatic target search and identification extending the operative and productive time on the pole. Integrated into existing search methods, foreign targets are ignored during the search process so the total station only stops at the pole equipped with the AP20. A lock onto a foreign target is prevented, manual target checks are reduced, and work can begin immediately.

To provide this functionality, the AP20 includes a ring of 10 LEDs that transmit an optical signal with a specific identifier (ID) coded in its pulse frequency. This signal can be read by the PowerSearch (PS) receiver. A total station with PS capability is therefore mandatory to use TargetID functionality. The emitted frequency is set via the according ID number within the field software and allows 16 different IDs. After a Bluetooth connection is established, the total station or field controller automatically synchronises the chosen ID number with the connected AP20 and later one searches for this identifier and its corresponding target.

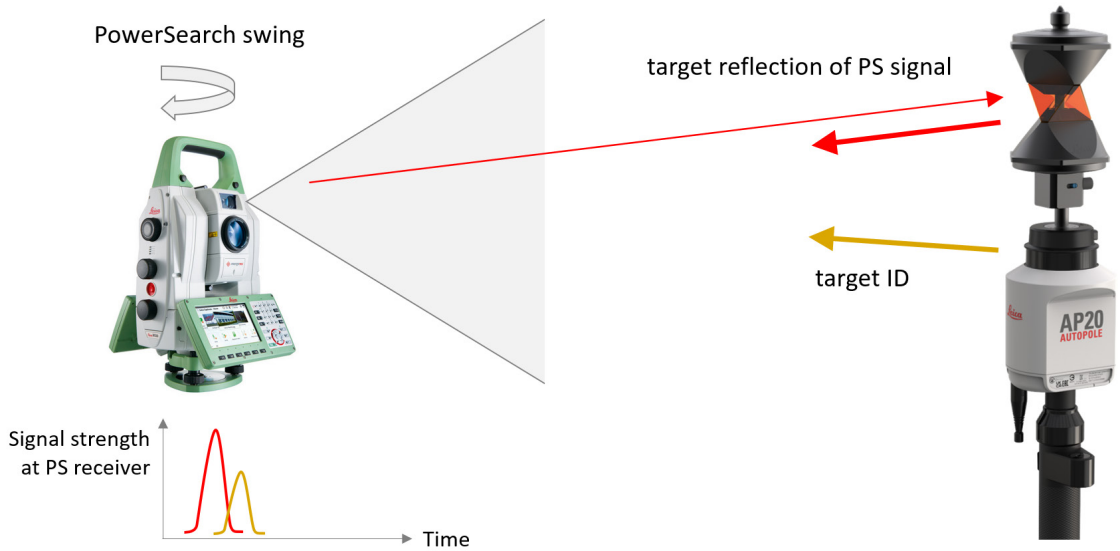

Figure 8: Schematic illustration of incoming signals on PS receiver, which are used to identify and lock target.

Once the user starts a target search via the field software, the following is automatically performed.:

1. Total station triggers AP20 to enable target ID transmission.
2. Total station starts horizontal search movement
3. Total station's PS receiver monitors incoming target reflections and target ID frequency from AP20.
4. Only if the correct target ID is detected, horizontal search stops and telescope aligns towards Hz direction of the target ID's peak signal.
5. Automatic Target Recognition (ATR) performs a vertical search and aims to the optical centre of the attached target.
6. After search is successfully complete, AP20 automatically disables target ID emission.

The wireless communication via Bluetooth makes it possible to change the desired ID number by setting it within the total station or field controller's field software. The AP20 is synchronised automatically. This connectivity also informs the AP20 about the start and end of the total station's search procedure. The ID transmission is only active if a search is in progress.

Figure 9: The AP20 allows work to continue uninterrupted even on busy sites with multiple operators.

5.2 Benefits of TargetID

When several crews are present on site and equipped with the AP20, individual operators can coordinate their IDs before starting work. In this case, up to 16 AP20 operators could work on the same site without interference during target searches. Even if two operators set the same ID, the probability for interference is low since ID transmission is not permanently active, but only during the search of the individual total station. As an additional benefit, this saves battery consumption.

By separating the source of the ID signal from the measured (optical) target, the morphology enables compatibility with any existing Leica Geosystems reflector that fits on the pole. Thus, TargetID functionality works regardless of whether a round prism or 360° prism is attached and the measurement performance onto the precise target centre remains at the high level of the total station.

TargetID functionality also results in an extended and more robust search range under very humid and rainy conditions compared to conventional PS. Due to the additional target ID information, a strict signal strengths analysis to filter foreign reflections is not necessary any more. Also, as the AP20 is only transmitting its target ID in one way towards the total station, it is less affected by rain in the optical channel.

TargetID ensures the AP20 fits into existing workflows and instrument setups, while eliminating downtime and allowing simultaneous work to carry on uninterrupted.

6. CONCLUSION

Compatibility

The AP20 is compatible with automated total stations including the Viva TS16*, Nova TS60/MS60 and iCON robots iCR70/80/80s. These instruments only require a firmware update to v7.00 (or higher) of Leica Captivate or Leica iCON field software to support the new AP20 features.

Summary

The new AP20 AutoPole converges latest sensor technologies to effectively automate the last manual processes in an otherwise digital workflow with Leica Geosystems total stations.

When all three AP20 functionalities are used in conjunction, operators can:

- Measure points faster without the need to level the pole.
- Measure previously inaccessible points and increase direct point measurements without offset calculations or additional total station setups.
- Measure safely on construction sites, along roadways, and in other settings with potential hazards through flexible measuring options (height and tilt) while retaining focus on taking the measurement rather than levelling or recording height changes.
- Measure in difficult weather conditions while maintaining lock with the total station, getting work done on schedule despite inclement weather.

Value

Make the most out of your automated total station investment with the AP20. Testing demonstrated the AP20 increases productivity with time savings across workflows and applications. Faster task completion with high accuracy data means less rework and post-processing, resulting in significant cost savings.

Figure 10: Increased access to obscured points and streamlined one-person operation result in enhanced safety and cost savings.

* Tilt compensation requires the tracking capability and can be used with the TS16 A/G/P/I. TargetID requires PowerSearch capability, and can therefore be used with the TS16 P/I.

References

Dainty, P. (2022), Leica AP20 AutoPole - Introduction and how to use with Captivate - Online Learning Course. https://learning.leica-geosystems.com/course/view.php?id=303

Eder, R. (2022), Evaluierung der Einsatzfähigkeit einer neuartigen Lotstocktechnologie. Diploma Thesis, Hochschule für Wirtschaft und Technik Dresden.

Leica Geosystems (2022), How to effectively initialise the Leica AP20 – Online Learning Video. https://share.vidyard.com/watch/dy1GeeJGTUUXVqoKzxaYfW

Leica Geosystems (2022), "Innovative Surveying Technology Helps Speed Pipe Installation and Road Renewal: The Leica AP20 AutoPole improves survey and stakeout workflows with automation." Online Article. https://leica-geosystems.com/case-studies/surveying-and-engineering/innovative-surveying-technology-helps-speed-pipe-installation-and-road-renewal.

Luo, X., Schaufler, S., Carrera, M., Celebi, I. (2018), High-precision RTK positioning with calibration-free tilt compensation. In: Proceedings of FIG Congress 2018, Istanbul, Turkey, May 6–11, 17 pp.

Maar, H. (2022), Automated Pole Functionalities for Advancing Productivity of Total Station Workflows. In: Proceedings of FIG Congress 2022, Warsaw, Poland, September 11-15, 2022. https://fig.net/resources/proceedings/fig_proceedings/fig2022/papers/ts08g/TS08G_maar_11353.pdf

Biographical note

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