Leica Nova MS60
White paper

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Leica Nova MS60 – The new experience in measuring technology

Abstract

Outstanding and enhanced total station functionality, GNSS connectivity, high resolution digital imaging and 3D laser scanning; this is mergeTEC, a key component of the Leica Nova MultiStations.

mergeTEC not only merges technologies but also data. Images are referenced to total station measurements, and total station measurements are complemented by 3D point clouds, which themselves are coloured by the image information. All data perfectly fits within the same coordinate system, globally referenced by GNSS measurements or by measuring known points.

How the Leica Nova MS60 – the world's first self-learning MultiStation – evolved from its predecessor, the Leica Nova MS50 [1], to a measurement solution allowing significant automation improvements embedded in a new intuitive field software will be presented in this white paper.

Introduction

MS60 embodies 90 years of innovative thinking of Leica Geosystems to develop precise, reliable and flexible technologies.

The MS60 is part of the Leica Nova solution, which contains:

- Outstanding surveying instruments, built on the latest technologies,
- Integrated dataflow, straightforward and easy to understand workflow,
- Services and support, accessible worldwide.

The Nova MS60 includes precise 3D laser scanning, extensive and precise total station capabilities, enhanced automation performance, digital imagery and GNSS connectivity. Thanks to mergeTEC, the Nova MS60 not only combines the hardware but also merges the data itself; images are synchronised with 3D laser scans and the scans tied into total station measurements. This allows the users to decide on site which measurement technology to use to fulfil measurement tasks.

Figure 1 – Leica Nova MS60 MultiStation

The results are available directly in the field, for example the volume of a stockpile derived from point clouds that have been scanned with the Nova MS60. Both single point measurements and scans are visualised on a bigger 5" screen using the 3D viewer of Leica Captivate, the intuitive field software.

Leica Nova MS60 – the world's first self-learning MultiStation

The Nova MS60 features outstanding precision, accuracy, efficiency, quality and versatility. The MultiStation provides an angular accuracy of 1" (according to ISO 17123-3) and an electro-optical distance measurement system (EDM) based on wave form digitiser technology. The EDM measurement accuracy is 1 mm + 1.5 ppm onto prism (according to ISO 17123-4) and 2 mm + 2 ppm onto any surface (see Table 1).

Table 1 – Measurement Performance

Angular accuracy (according to ISO-17123-3)	1" Hz and V
Distance measurement accuracy onto GPR1 prism[1] (according to ISO-17123-4)	1 mm + 1.5 ppm
Distance measurement accuracy onto any surface[2] (according to ISO-17123-4)	2 mm + 2 ppm
Distance measurement range onto prism[1]	1.5 m up to 10,000 m
Distance measurement range onto any surface[2]	1.5 m up to 2,000 m

The mechanical design of the MultiStation has been developed for highest protection against environmental conditions. The Nova MS60 fulfills IP65 standards and

[1] Overcast, no haze, visibility about 40 km, no heat shimmer
[2] Object in shade, sky overcast, Kodak Gray Card (90% reflectance)

withstands the MIL standard blowing rain test. This is the highest protection for any robotic total station currently available.

To withstand harsh conditions, the Nova MS60 fulfills IP65 standard and the MIL standard blowing rain test[3].

The Nova MS60 introduces new ATRplus technology, which increases the measurement performance both on static and especially on dynamically moving targets. ATRplus with a dynamic and automatic energy control and new algorithms automatically adapts to challenging and changing environmental conditions. This results in higher measurement ranges and leads to an increased user comfort due to reduced manual settings [2]. Furthermore, enhanced PowerSearch functionalities, such as the PowerSearch Filter and Dynamic Lock, supports the Nova MS60 to find the target of interest quickly and efficiently, even if it's moving.

ATRplus reduces possible error sources such as wrong user settings and expands the boundaries of automated surveying.

A combined USB – RS232 interface at the non-rotating part of the MultiStation as well as Bluetooth® and WLAN ensure fast data transfer. A long-range Bluetooth® radio handle can be connected to the MultiStation and ensures remote working ranges up to 1,000 m to field controllers such as the CS20 and the CS35 tablet.

The MultiStation offers enhanced imaging functionality by implementing two cameras: the overview and the telescope camera. Both cameras deliver 5 megapixel resolution images for accurate image assisted surveying and high quality documentation by profiting from a bigger 5" onboard screen.

The overview camera is located in the upper part of the telescope, while the telescope camera is located in line with the optical axis and has the full 30x magnification of the telescope optics.

The live video stream, which is provided with up to 20 frames per second on the display, can easily be switched between overview camera and telescope camera.

Autofocus functionality increases the measurement efficiency and reduces the fatigue of the operator's eyes.

A unique functionality of the Nova MS60 is 3D laser scanning. The scanning functionality is seamlessly integrated into the standard workflow of a total station. This allows the 3D laser scans to always be in the current coordinate system of the MultiStation. Known setup routines (e.g. Set Orientation, Known Backsight, Resection, Orientate to object) are used and the point clouds are automatically registered directly in the field. The new onboard 3D viewer allows the user to verify and check the point clouds for completeness directly in the field. Scan shadows can be identified on site, which minimises the necessity for costly returns for re-measuring. Surfaces and volumes can be calculated with the 'QuickVolume' or analysed with the 'Inspect surfaces' application. Additional single measurements from the setup complete the data.

mergeTEC

mergeTEC is the fusion of the latest innovative technologies and combines:

- Enhanced and outstanding total station functionality
- GNSS connectivity
- Digital imaging
- 3D laser scanning

Consequently, mergeTEC enables the user to select the appropriate measurement technology for the corresponding measurement tasks within one instrument. mergeTEC also guarantees that the captured complex 3D data is referenced to each other. The user does not need to care about referencing data among a multitude of scans, images and TPS measurements. He can use known TPS setup routines such as Set Orientation, Known Backsight, Resection or the new method 'Orientate to object' that allows to work in an object coordinate system where the z-axis is not necessarily parallel to the vertical axis of the instrument.

Outstanding Total Station Functionality

The Nova MS60 emphasises enhanced and outstanding total station functionality. The motorisation, based on Piezo-technology, allows very fast telescope movements without any noise pollution.

The MultiStation uses a distance measurement system based on wave form digitiser technology that allows highly precise and fast measurements. Ranges onto any surface are possible up to 2,000 m and onto a single prism up to at least 10,000 m.

[3] MIL-STD-810G, Method 506.5-I

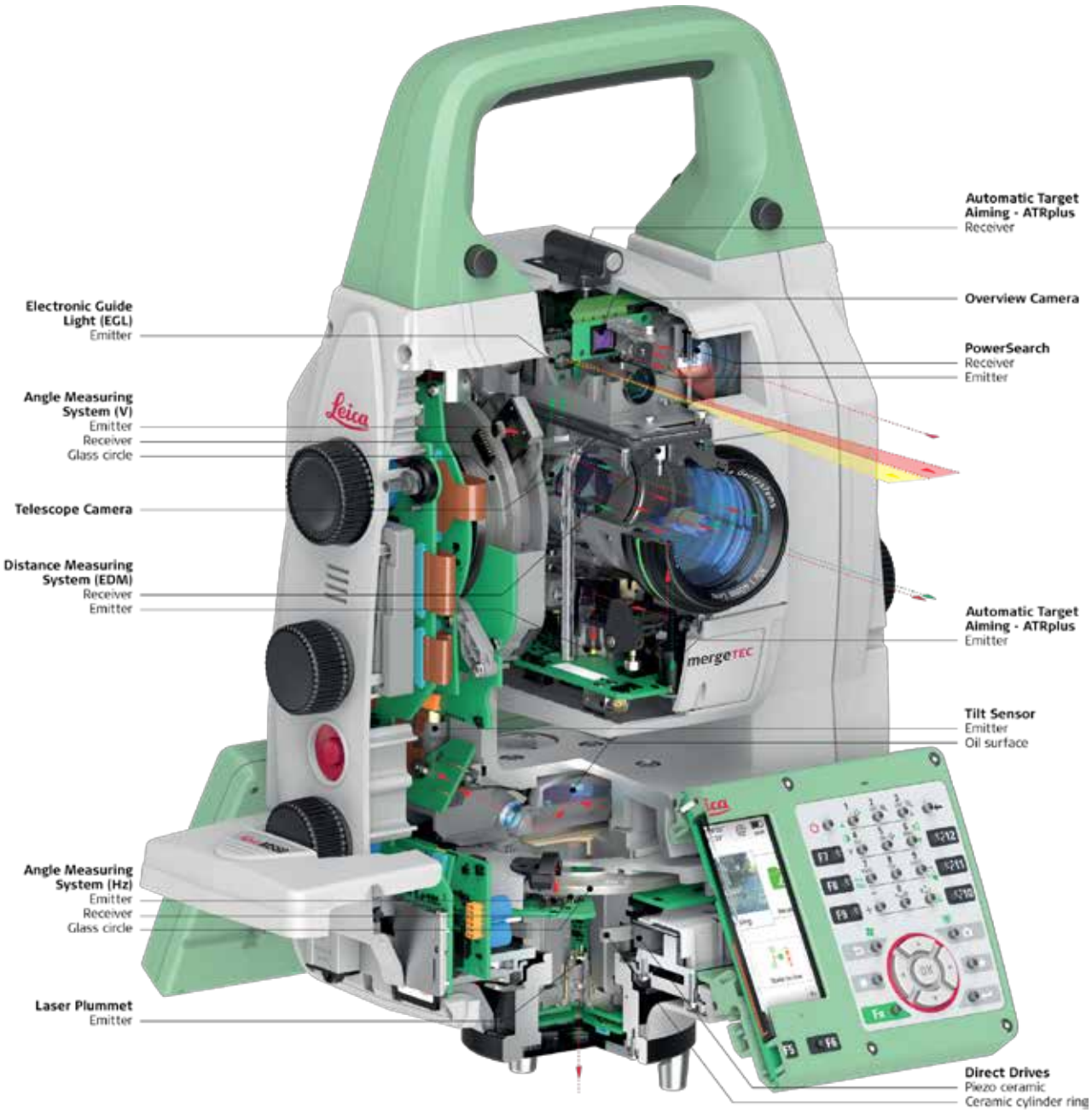

Figure 2 – Cross-section of the Leica Nova MS60 MultiStation

Leica Captivate

The Nova MS60 uses the engaging Leica Captivate field software. Captivate ensures the complete integration of the measurement technologies such as imaging and 3D laser scanning into the standard measuring workflow. Familiar apps and touch technology enables the user to capture and manage complex data in an intuitive and professional way.

Hard and software improvements allow reduced and simplified settings in the measure and target panel, so that the user can fully concentrate on the surveying work to be done (see Table 2).

Table 2 – Comparison of different settings in SmartWorx Viva with ATR and in Captivate with ATRplus.

	SmartWorx Viva	Captivate
Visibility (environmental condition)	▪ Good ▪ Rain & Fog ▪ Sun & Reflection	▪ No settings needed
Range information	▪ High dynamics at short range	▪ No settings needed
Distance measurement mode	▪ Continuous ▪ Continuous+	▪ Continuously
Dynamic information	▪ Allow to lock in on the fly setting	▪ Direct access to Wait & Lock

With more powerful coding possibilities and by the use of the new 3D viewer, both single point measurements, line work and scans can be visualised at a glance. By virtually navigating through all collected data in 3D perspective, detailed areas of interest can be checked for completeness in an efficient and simple way.

Dedicated onboard software applications, such as 'Inspect surfaces' allow point cloud analyses directly in the field and extend the application area of the MS60 to tunneling or road applications, for example.

A smooth data transfer ensures a flawless and complete delivery to post-processing software, such as Leica Infinity.

Enhanced Automation using ATRplus

With previous generations of total stations, the measurement professional had to consider environmental conditions in order to achieve the best results. Visibility settings, high dynamics at short ranges and 'lock in on the fly' had to be set correctly. Environmental conditions, however, can change during the measurement period.

ATRplus with a dynamic and automatic energy control and new algorithms can automatically find the optimal parameters in challenging and changing environmental surroundings, which results in higher measurement ranges for any conditions without changing the settings manually (see Figure 3).

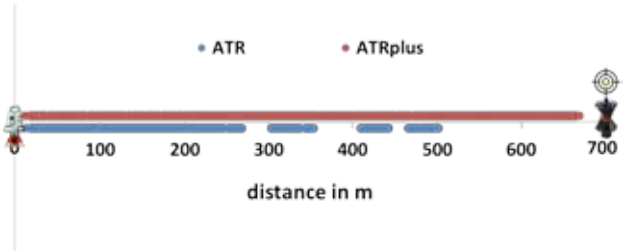

Figure 3 – Following and measuring onto a prism under difficult (rainy) conditions.

A tight control loop in combination with a better temporal measurement synchronisation allows a more stable lock so that a highly dynamic moving target can be followed without losing it.

By nature, reflective objects, such as safety vests or traffic signs, located nearby your target of interest can also throw back a portion of the emitted laser pulse. To avoid a measurement or a lock onto such non-relevant targets, a spot analyser evaluates the shape of the detected spot and decides if it is a real prism spot or another reflection. If it detects a non-prism spot during a single measurement, it stops the measurement and shows an appropriate message.

The spot analyser of ATRplus can detect reflective objects like safety vests or road signs as non-targets.

In order to avoid similar negative impacts caused by foreign light sources, such as reflections from car headlights (see Figure 4), bright construction illuminations or the sun, ATRplus uses alternating laser power levels in terms of dark, gray and bright images. While the prism reflection decreases according to the reduced ATRplus laser power, the foreign light sources stay the same and can therefore reliably be detected and avoided.

Figure 4 – ATRplus (left) is correctly locked onto the prism on the top of the car. ATR (right) tries to lock onto the car headlights.

History logs allow the detection of several prisms in the field of view of the telescope. Thus, all identified targets are labelled with an internal temporary ID and stored in the history. If the currently locked prism (marked as the prism in use) suddenly disappears, the instrument turns into prediction mode and will not lock onto a second nearby prism, because this is known in the history as an irrelevant prism. History logs prevent a lock on a foreign prism after a loss of lock and are valid until the end of the prediction phase.

PowerSearch Filter

Targets far off the current field of view of the telescope can be found with the PowerSearch technology in a fast and efficient way. For specific situations where a large number of fixed and non-relevant targets are on site (e.g. for stationing the instrument), the PowerSearch filter is introduced with the latest generation of Leica Viva and Nova total stations and MultiStations. The PowerSearch filter allows an initial learning of all visible fixed targets around, so that those targets will be ignored when performing a PowerSearch to your target of interest.

Figure 5 – Using the PowerSearch filter to ignore non-relevant targets.

Dynamic Lock

With the release of Leica Captivate 2.0, the Dynamic Lock was introduced for the Nova MS60 MultiStation. With this new functionality, users no longer need to stand still and wait until the prism is found and followed. PowerSearch and ATRplus sensors work simultaneously to search an enlarged field of view and lock onto a target even if it is moving. This is especially beneficial for highly dynamic applications, such as machine control, where the driver does not want to stop the machine, or staking out, where the pole is often laid down on the ground and therefore out of sight [3]. The Dynamic Lock is used in following search methods:

- Wait & Lock
- CubeSearch

Wait & Lock puts the instrument into an initial motionless state with the sensors online so that a target gets dynamically locked as soon as it is crossing the instrument's horizontal sighting. CubeSearch can automatically be started after a loss of lock and will actively search a cube area around the target's last known position and re-lock onto it while moving (see Figure 6).

Figure 6 – CubeSearch using Dynamic Lock onto a moving target.

GNSS Connectivity

GNSS is fully integrated in the workflow and the data structure. The Nova MS60 allows SmartStation and SmartPole setup with several Leica Geosystems GNSS smart antennas. This enables direct global georeferencing without the need for sighting known points. Thanks to enhanced Leica Geosystems GNSS technologies, the position can be defined quickly and reliably.

Digital Imaging

The MultiStation features two 5 megapixel digital cameras – the overview camera and the telescope camera which is located in the optical axis of the telescope (see Table 3).

The live video stream can be shown on the instrument's display or on the controller and can easily be switched between overview camera and telescope camera. When standing at the instrument, the user has the choice between looking at the live video stream and looking through the telescope. The autofocus functionality ensures a sharp image by a single button press.

Table 3 – Technical data of overview and telescope camera.

	Overview Camera	Telescope Camera
Sensor	5 MP CMOS	5 MP CMOS
Field of view (hz, v)	15.5° x 11.7° 19.4° diagonal	1.3° x 1.0° 1.5° diagonal
Magnification / zoom	8x zoom	30x optical magnification, 8x zoom
Live view update rate	20 Hz	20 Hz
Focus	Fix focus 2 m to infinity	Focusing range: 1.7 m to infinity, autofocus
Sensor pixel – angle relationship	One pixel corresponds to 67 cc	One pixel corresponds to 5 cc
Display resolution	WVGA	WVGA

Digital imaging on the Leica Nova MS60 enables following enhanced applications:

- Image assisted surveying
- Image documentation
- Measure points from images

Image Assisted Surveying

Image assisted surveying supports the operator with Tap & Turn and 3D data overlay functionality, making the measurement process faster, simpler and more comprehensible. Tap & Turn is a comfortable and efficient way to measure using the live video stream. The instrument turns to where the user taps on the display. The 3D data overlay functionality increases the measurement quality in terms of completeness by displaying measured points and control points as 3D data overlay.

The overview camera helps the user to roughly aim onto the target. By using the calibrated digital crosshair of the telescope camera, the target can be precisely aimed based on the live video stream and the 30x magnification (Figure 7). An angular accuracy of 1" (according to ISO 17123-3) of the measurement can be achieved by using the live video stream from the telescope camera to aim onto the target.

Figure 7 – Scenery displayed with live video stream: once with the overview camera and once with the telescope camera.

Image Documentation

High resolution images can be captured with the overview camera and the telescope camera. These images can be directly linked and referenced to the measurements. The possibility to capture images of each measured point improves the documentation of the field work. Furthermore, sketching functionality allows making notations directly in the images for better understanding of what has been measured.

Measure points from Images

The high resolution images can be used for photogrammetric processing as well. The photogrammetric resolution of 1 pixel of the telescope camera corresponds to 5 cc, which results in a resolution of 2 mm at a distance of 200 m.

Leica Geosystems' office software, Infinity, allows for the use of the full potential of the collected images from the field. Missing survey points can be re-measured in the office by the use of images from at least two stations capturing the same object of interest. Without the need of photogrammetric expertise, the operator can use the mouse cursor to

pick common target points in the given images (Figure 8).

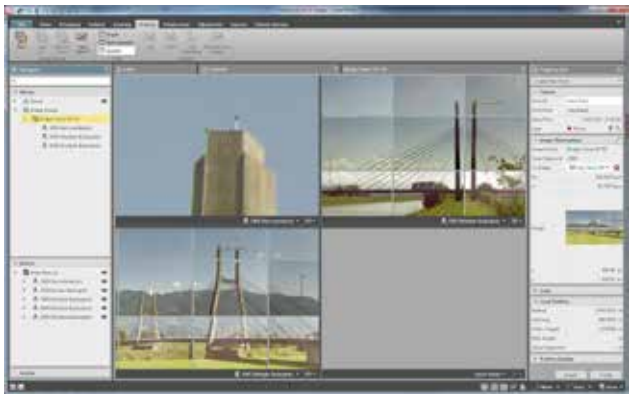

Figure 8 – Measure points from images using Leica Infinity.

3D Laser Scanning

Thanks to the electro-optical distance measurement system based on the wave form digitiser technology, the fast and precise Piezo-motorisation, the high processor power and Leica Geosystems' scanning expertise, the Nova MS60 integrates 3D laser scanning functionality into the regular measuring workflow of a total station. Detailed point clouds can be combined with topographic survey data.

EDM – Electro-Optical Distance Measurement

The Nova MS60 features an electro-optical distance measurement system based on the wave form digitiser technology (WFD). The advantages of the WFD technology are fast distance measurements, a small laser dot size, high measurement accuracy and long ranges that are available at the same time (see Table 4). The WFD principle represents a key element of the 3D laser scanning functionality and is shortly explained below.

The WFD based EDM sends out short pulses. A small part of each pulse gets directly guided onto a photo detector inside the telescope and serves as internal calibration measurement, called start pulse. The rest of the pulse is emitted out of the telescope and reflected by the object, therefore called stop pulse. Both pulses are digitised as full waveform and accumulated from multiple signals (Figure 9). The time difference between accumulated start and stop pulse is used to calculate the distance as it is done in a standard time-of-flight method [4].

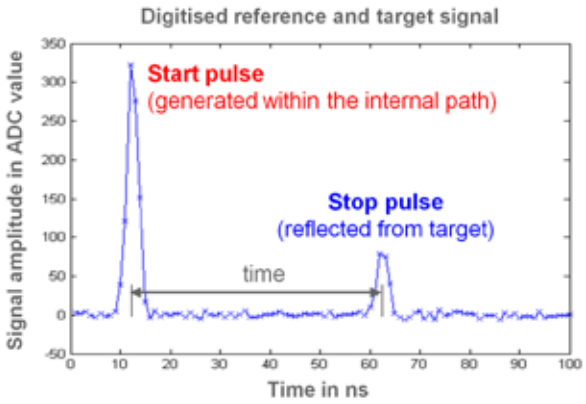

Figure 9 – Measurement principle of the WFD technology.

One advantage of the WFD is the flexible configurability in terms of the number of accumulated signals. Depending on the field of application the EDM performance can either focus on achieving highest accuracy, maximum speed, longest range or a combination of the three.

Table 4 – Comparison of the different EDM technologies.

Technology	Description
WFD	▪ Fast measurement time ▪ Small laser spot size similar to phase-shift ▪ High measurement accuracy ▪ Long ranges ▪ Configurable: accurate but more time required or fast with less accuracy
Time-of-flight	▪ Fast measurement time ▪ Large laser spot size ▪ Lower measurement accuracy ▪ No measurements if signal to noise ratio is too low
Phase-shift	▪ Long measurement time ▪ Small laser spot ▪ Highest measurement accuracy

Scanning Workflow

The close integration of the scanning capabilities into standard total station routines makes it very straight forward to use the 3D laser scanning capabilities of the MultiStation even for operators without scanning experience.

The scan area can be precisely defined using the live video stream to scan only the area of interest (see Figure 10).

Figure 10 – Live video stream with polygonal scan area definition.

Different scan modes allow the user to get the best data within the available time and object properties, such as range and surface. Depending on the scan mode, ranges up to 1,000 m can be measured (see Table 5).

Table 5 – Leica Nova MS60 3D laser scanning specifications.

Scanning speed	1,000 pts/s up to 300 m
Scanning range	Up to 1,000 m
Scanning precision (range noise)	< 1 mm @ 50 m 1 σ, Kodak Gray Card (90% reflectance)
Onboard point cloud visualisation	3D viewer including true colour point clouds

The Nova MS60 features four scan modes with a maximum measurement frequency of up to 1,000 points per second. Figure 11 shows the maximum scan ranges for the different scanning frequencies.

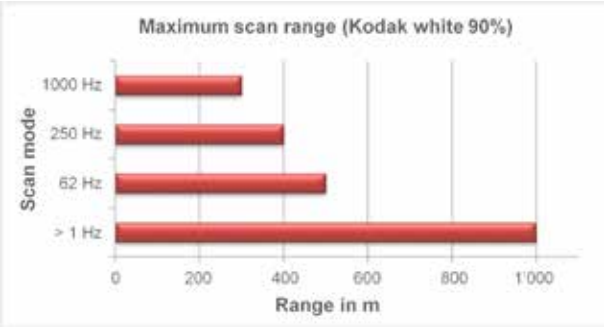

Figure 11 – Maximum scan ranges for the different scanning frequencies.

The high quality of the Nova MS60 scan can be recognised by the low range noise values (below 1 mm at 50 m). The range noise describes the standard deviation of the scan points' residuals to a modelled surface plane. Depending on the scan mode, the scan noise can even be reduced (see Figure 12).

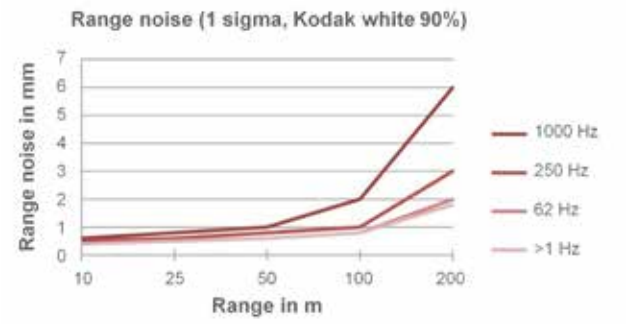

Figure 12 – Range noise (1σ) of the different scan modes in relation to the scan range.

For an even higher point cloud quality, there are two additional point cloud filter settings available. The outlier filter removes single points, which can be caused by unwanted reflections or objects passing through the laser beam while scanning. A so-called mixed-pixel filter removes scan points, which get a mixed distance if the laser beam hits two surfaces at the same time.

Point clouds can be coloured with the values of the returned laser beam intensity, the true colours from the optionally captured panoramic image, or by a single colour for each setup.

Based on known setup routines the point clouds are automatically referenced to the actual instrument setup (see Figure 13). There is no need to setup and scan additional reference targets. Furthermore, atmospheric and geometric corrections are applied to the point cloud in real time during the scanning procedure.

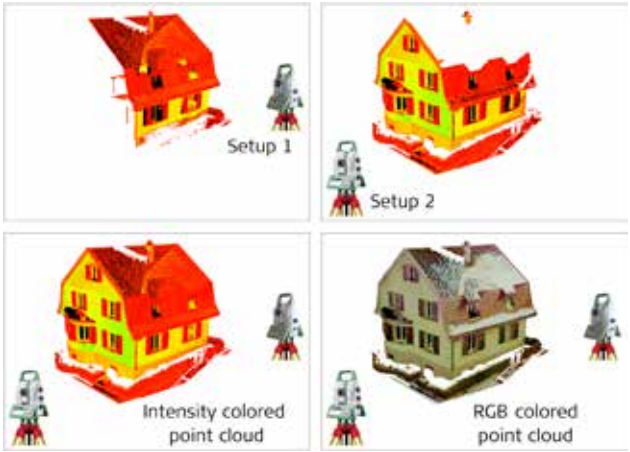

Figure 13 – Auto-registration of the point clouds directly in the field.

The MS60 offers the new 3D viewer which allows the 3D visualisation of the point clouds together with other single point and line measurements (see Figure 14). By zooming, panning and rotating, the completeness of the data set can easily be verified. Doing the completeness check directly in the field can avoid a costly revisit of the site and expensive re-measuring of the object.

Figure 14 – 3D viewer for single point and point cloud visualisation in the field.

Data Flow

The data handling from the field to the office and vice versa and the data processing in the office are crucial for a successful project. The MS60 offers a seamless data flow including data processing software for the office:

- Leica Infinity
- Leica MultiWorx
- Leica Cyclone
- Supporting programmes from software partners

Infinity supports the processing of various measurement, imaging and 3D laser scan data from the Nova MS60. It enables the adjustment of single point measurements and update of 3D point clouds accordingly and supports standard scanning file format such .e57 and .pts.

Leica MultiWorx is a plugin for Autodesk's AutoCAD and Civil 3D and enables users to work with rich 3D point clouds in their familiar CAD environment. MultiWorx provides simple and powerful tools for navigating point clouds and creating deliverables.

Leica Cyclone – the powerful point cloud processing software from Leica Geosystems – features the direct data import from the MS60 using XML export. Advanced point cloud users can directly combine MultiStation point cloud data with point clouds from Leica Geosystems HDS laser scanners.

Summary

In a single instrument, with the size and weight of a total station, the Nova MS60 combines total station capabilities with enhanced automation performance, digital imaging, GNSS connectivity and 3D laser scanning – all embedded in the intuitive Captivate field software.

mergeTEC combines most advanced measurement technologies with a thought-through workflow to assure complete performance during all steps, from the data collection, verification and processing to the deliverables.

Enhanced Total Station Functionality

Highly accurate angle and distance measurements, a long-lasting design and easy-to-use apps are key elements of modern total stations and therefore fully integrated in the Nova MS60. With improved automation functionalities using ATRplus, the MultiStation makes survey and stake out applications more efficient, even under challenging environmental conditions.

Digital Imaging

Enhanced digital imaging technology including an overview and a 30x magnifying telescope camera enables accurate image assisted surveying, extended image documentation and measuring points from images using the office software Infinity.

3D Laser Scanning

3D laser scanning is fully integrated into the regular measuring workflow and can be combined with survey data, measurements and images. Extended onboard functionality delivers automatically referenced point clouds directly in the field.

The Nova MS60 delivers a new experience in measuring technology enabling the user to make the right decision in the field.

References

[1] Grimm, D. E. and Zogg, H.-M. (2013). Leica Nova MS50. White Paper, Leica Geosystems AG, Heinrich-Wild-Strasse CH-9435 Heerbrugg.

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Distance meter (Prism), ATRplus & PowerSearch:
Laser class 1 in accordance with IEC 60825-1 resp. EN 60825-1

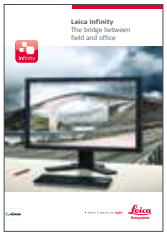
Laser plummet:
Laser class 2 in accordance with IEC 60825-1 resp. EN 60825-1

Distance meter (Non-Prism):
Laser class 3R in accordance with IEC 60825-1 resp. EN 60825-1

Leica Nova MS60
Brochure

Leica Viva TS16
Brochure

Leica Viva GS16
Brochure



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